Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 107-116, 2016

Interaction Effects between P and S in Soil on the Mobility of N, P and K in Rape (*Brassica Campestris* L.)

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Published : 30.10.2017

Abstract

Field experiment was conducted in an aeric endoaquept to study the interaction effect between P and S on the mobility of N, P and K in different parts of oilseed rape (Cv.B-9) using nine treatment combinations in a randomized block design (RBD) replicated thrice. The results reveal that the individual application of both P and S showed an increase in N, P and K content in stem and seed of rape, being greater magnitude with their higher rates. As regards to the root N, P and K content in rape, it was observed that the individual application of P increased a greater magnitude compared to individual of S, being greater with their increasing rates. The results further show that the amount of K content in stem, seed and root of rape has been found to be increased with individual application of P and S, being higher with their increasing levels, being further enhanced with their interactions. It is interesting to note that the rate of absorption of K by stem was much greater compared to N and P absorption of the same, suggesting greater mobility of K within the plant. The N, P and K contents in stem : root and seed : stem have been found to be varied by the different interaction combinations of P and S applications. The ratio of N in stem : root and seed : stem highest (0.88) in P_0S_0 and 38.18 in P_2S_1 respectively which suggest that the greater mobility of N from stem to seed compared to root : stem. Comparing the results of interaction between P and S on the mobility of P and K it shown that the highest stem : root and seed : stem were recorded as 4.61, 1.03, 2.40 and 0.58 in the treatments P_1S_0 , P_2S_0 , P_1S_0 and P_0S_0 respectively. The yield of rape seed has been found to be increased with the individual application of both S and P irrespective of their rates. Such increase in yield of rape has been found to be further enhanced in the treatment P_1S_2 (8.1 q /ha) where P at 30 and S at 30 kg /ha was applied combinedly. The results further indicate that the mobility of N, P and K towards seed might be beneficial for maintaining healthy, nutritious and quality seeds vis – a – vis enhancing oil content in rape.

Key words : interaction, mobility, phosphorus, rape, sulphur

Introduction

The application of phosphorus increases the nutrient uptake, yield and quality of oil seed crops especially rape and mustard. However, such increase in nutrient uptake and yields might be further enhanced when phosphorus is applied combinedly with sulphur, of the various factors determining plant growth, supply of nutrients either from the native soil or supplemented through applied fertilizers, their rate of absorption, distribution among functional sites and degree of mobility within the plant are very important. The application of role of phosphorus increases the nutrient uptake yield and quality of oil seed crops especially rape and mustard. However, such increase in nutrient uptake and yields might be further enhanced when phosphorus is applied combinedly with sulphur (Das, 2007), of the various factors determining plant growth, supply of nutrients either from the native soil or

supplemented through applied fertilizers, their rate of absorption, distribution among functional sites and degree of mobility within the plant are very important. Keeping these in view, the present study was undertaken.

Materials and Methods

The present study was under taken in the field (University Farm Baruipur) with nine treatment combinations of P and S in a randomised block design replicated thrice using rape (Cv. B – 9) as a test crop. The study was concentrated on the translocation of N, P and K within the plant, rape. P_0 - control, P_1 - 30 kg /ha, P_2 – 45 kg/ha, S_0 – control, S_1 – 15 kg/ ha, S_2 – 30 kg/ha, N- 80 kg/ ha, K2O- 40 kg/ha.

$S_0P_0 = T_1$	$S_1P_0 = T_4$	$S_2P_0 = T_7$
$S_0P_1 = T_2$	$S_1P_1 = T_5$	$S_2P_1 = T_8$
$S_0P_2 = T_3$	$S_1P_2 = T_6$	$S_2P_2 = T_9$

The physico-chemical properties of soils as well as available N, P and K in soils and total N, P and K contents from plants were analysed following the method described by Jackson (1973). Nitrogen was determined by Kjeldhal method. Phosphorus and Potassium were determined by spectro photometrically and flame photometrically respectively.

Nitrogen Content in Rape

A. Whole Plant :

The highest N (4.17 g/kg) content was recorded at 42 days of crop growth when higher levels of phosphorus at 45 kg/ha and sulphur at 30 kg/ha was applied simultaneously suggesting a positive interaction effect between P X S with respect to N content in stem. N content in stem. The mean effects of S and P application on the changes in N content in stem (whole plant) are depicted in figures 1 and 2.

Nitrogen content in Rape Seed

B. Seed :

The application of S at 15 kg/ha has been followed to be superior which showed highest N content (42.93 g/kg) in seed compared to its highest level at 30 kg/ha, whereas the amount of N content in seed was recorded highest (42.0 g/ kg) when P at 45 kg/ha was applied (Table 1) However, it is interesting to note that the amount of N content in rape seed has been found to be further increased when P and S was applied combinedly, being highest content (44.8 g/kg) N of seed in the treatment P_1S_1 when P at 30 and S at 15 kg/ha was applied altogether. Das (2015) also reported similarly where combined application of P and S increased N, P and K contents in seed compared to their individual application.

Nitrogen Content in Root

C. Root :

The results reveal that the root N content did not vary much due to individual application of S, at its different levels whereas the same content in root varied due to separate application of P.

Phosphorus Content in Rape

A. Whole Plant **:**

Comparing the results of interaction between P and S, it was found that the amount of P content in stem has been recorded to be varied with P and S interactions at their different levels, being highest amount (4.08 g/kg) in the treatment P_2S_2 when P at 45 and S at 30 kg/ha was applied combinedly. The result suggest that the interaction effect between P and S was found positive and synergistic with respect to P content in stem of rape.

The mean effect of S and P application on the changes in P content in stem are depicted in figures 3 and 4.

Fig. 1 Mean effect of S application on the nitrogen content in stem (whole plant).

TABLE 1. Nitrogen content (g/kg) in seed as affected by combined application of P and S in soil growing Rape (*Brassica campestris* L.) (Mean of three replications).

Treatment	P_0	P_1	P_2	Mean
S_0	42.0	41.3	42.0	41.77
S_1	42.0	44.8	42.0	42.93
S_2	39.9	35.0	42.0	38.97
Mean	41.3	40.37	42.0	

Phosphorus content in Rape Seed

B. Seed **:**

As regard to the combined applications of P and S (Table 2) it was observed that the amount of P content was always higher due to application of P and S at their different levels, being highest (5.65 g/kg) in the treatment P_2S_2 when P at 45 kg/ha and S at 30kg/ ha was applied combinedly, which might be explain by greater mobility of P within the rape in presence of S suggested an existence of synergistic relationship between them in relation to seed P content, the results of the present study might have some favourable effect in contributing seed phospholipid content of rape. The present study also finds support from the results reported by Jain *et al.* (1995).

Fig. 2 Mean effect of P application on the nitrogen content in stem (whole plant)

TABLE 2. Phosphorus content (g/kg) in seed as affected by combined application of P and S in soil growing Rape (*Brassica campestris* L.) (Mean of three replications).

Treatment	P_0	P_1	P_2	Mean
S_0	4.05	4.15	4.90	4.37
S_1	4.15	4.75	4.90	4.6
S_2	4.60	4.80	5.65	5.02
Mean	4.27	4.57	5.15	

Phosphorus Content in Root

C. Root :

With regards to separate application of S at its different levels, it was observed that the amount of P in root increased with S application, being highest (1.58 g/kg) with its highest level. Similar trend of changes in respect of P content in root was also recorded due to application of (1.71 g/kg) P at its highest level. The greater magnitude of increase however, was recorded due to application of highest level of P compared to corresponding levels of S which is obvious. As regards to the interaction between P and S, it was found that the P content in root was always higher with different combination of P and S interaction over that of absolute control (P_0S_0). However the P content in root was recorded highest (1.98 g/kg) in the treatment (P_2S_2) where combined application of P at 45 kg/ha and S at 30 kg/ha was made.

Fig. 3 Mean effect of S application on the phosphorus content in stem (whole plant).

Potassium Content in Rape

A. Whole Plant **:**

The results show that the amount of K content in stem progressively increased with the application of separate application of S and P and also due to their combined application. The magnitude of such variation, however, varied with individual and combined application of S and P. As regards to the S application, the potassium content in stem (whole plant) has been found to be highest (13.22 g/kg) in the treatment S_2 when S at 30 kg/ ha was applied, similar trend of changes in K content was also recorded due to application of P. Comparing the interaction between P and S, the amount of K content in stem varied significantly being recorded highest (13.84 g/kg) in the treatment P_1S_2 When combined application of P at 30 kg/ha and S at 30 kg/ha was made. The results further reveal that the magnitude of absorption of K by stem was much

TABLE 3. Potassium content (g/kg) in seed as affected by combined application of P and S in soil growing Rape (*Brassica campestris* L.) (Mean of three replications).

Treatment	P_0	P_1	P_2	Mean
S_0	7.01	4.29	5.72	5.67
S_1	6.27	7.73	6.55	6.85
S_2	5.96	4.79	4.89	5.21
Mean	6.41	5.60	5.72	

Fig. 4 Mean effect of P application on the phosphorus content in stem (whole plant).

higher amount compared to N and P absorption by stem, suggesting greater mobility of K within the plant which might be ascribed to the combined application of P and S containing fertilizers. Therefore, the results further suggest a synergistic effect between P and S with respect to K absorption by stem.

The mean effect of S and P application on the changes in K content in stem (whole plant) are depicted in figures 5 and 6.

Potassium Content in Rape Seed

B. Seed :

The results (Table 3) show that the K content in seed did show any significant variation due to individual and combined application of S and P. However, the application of S_1 at 15 kg/ha showed the highest amount (6.85 g/kg), while the amount of the same content did not show any variation due to application of P. As regards to the interaction between

TABLE 4. Yield of rape (q/ha) affected by interaction effect between P and S application in soil (Mean of three raplications).

Treatment	P_0	P_1	P_2	Mean
S_0	4.3	6.5	6.7	5.8
S_1	5.9	6.1	5.9	5.9
S_2	6.1	8.1	6.7	6.9
Mean	5.43	6.9	6.43	

Fig. 5 Mean effect of S application on the potassium content in stem (whole plant)

P and S, the K content did not effect much excepting the treatment P_1S_1 in which K content was recorded as 7.73 g/kg (about 10 % over absolute control).The results are in conformity with the results reported by Chaplot *et al.* (1991).

Potassium Content in Root

C. Root :

The amount of K content in root has been found to be increased with the individual and combined application of P and S. The magnitude of such increase, however, varied with levels of individual as well as combined application of P and S. The application of S at 30 kg/ha showed highest K content (7.65 g/kg) in root, where as the amount of the same content recorded highest (6.75 g/kg) with the application of P at 30 kg/ha.

Comparing the interaction effects of P and S, the amount of K content has been found to be further increased, being highest (8.94 g/kg) in the P_1S_2 treatment when P at 30 kg/ha and S at 45 kg/ha was applied combinedly. The results suggest a positive

TABLE 5. Percent increase in the yield of rape over control affected by interaction effect between P and S in soil.

Treatment	P_0	P_1	P_2	Mean
S_0		51.16	55.81	34.88
S_1	37.20	41.86	37.21	37.59
S_2	41.86	88.37	55.81	60.46
Mean	26.28	60.46	45.53	

Fig. 6 Mean effect of P application on the potassium content in stem (whole plant).

interaction effect between P and S with respect to K content in root since a significant amount of K content was increased over that of separate application of P and S.

Seed Yield

The yield of rape seed (Table 4) has been found to be increased with the individual application of both S and P irrespective of their rates The magnitude of such increase, however, varied with their increasing rates, being highest (6.9 q/ha) with an increasing rate of S while that of the same increase was recorded highest (6.9 q/ha) with the application of P at its lower rate (30 kg/ ha). Such increase in yield of rape has been found to be further enhanced in the treatment P_1S_2 (8.1 q /ha) where P at 30 and S at 30 kg /ha was applied combinedly. Jaggi and Sharma (1999) also reported similarly.

Percent Increase in Yield

The results (Table 5) reveal that the percent increase in yield of rape seed over control followed a similar trend of changes to that of yield of rape. However, the highest mean percent increase was recorded as 60.46 in the treatment S_2 when only S at 30 kg /ha was applied while that of the same percent increase was observed in the treatment P_1 when P was applied at 30 kg /ha . Such percent increase has been found to be further enhanced with their combined applications, being highest (88.37) in the treatment P_1S_2 when P at 30 and S at 30 kg /ha was applied combinedly. The results of the present investigation confirmed the results reported by Misra (2003).

Nutrient Ratio

Nitrogen, Phosphorus and Potassium ratios in different plant parts of rape.

The N, P and K contents in stem : root and seed : stem have been found to be moderated by the interaction between P and S. The ratio of N in stem : root and seed : stem was recorded as highest in the treatment P_0S_0 (0.88) and P_2S_1 (38.18) when no application of P and S, and P at 45 kg/ha and S at 15 kg/ha were applied in combination respectively suggesting a relatively greater mobility of N from stem to seed compared to root : stem (Table 6). As regards to the mobility of P and K within different parts of plants, it was observed that the highest stem : root and seed : stem were recorded as 4.61, 1.03, 2.40 and 0.58 in the treatment P_1S_0 , P_2S_0 , P_1S_0 and P_0S_0 respectively. The maintenance of greater ratios of nutrients in stem : root and seed : stem determines the mobility of nutrients from root to seed via stem. However, such mobility of N, P and K nutrients towards seed might be beneficial in maintaining healthy and quality seeds and hence increase oil content in rape.

Table 6. Nitrogen, phosphorus and potassium contents in stem : root and seed : stem of rape (*Brassica campestris* L.)

Treatment combination	N		P		K	
	Stover : root	Seed : stover	Stover : root	Seed : stover	Stover : root	Seed : stover
P_0S_0	0.88	7.92	4.60	1.00	2.20	0.58
P_0S_1	0.55	9.76	3.78	0.97	2.03	0.48
P_0S_2	0.74	7.98	3.73	1.00	1.73	0.46
P_1S_0	0.46	10.59	4.61	0.96	2.40	0.36
P_1S_1	0.64	12.44	3.66	0.97	1.99	0.61
P_1S_2	0.58	12.06	3.20	0.98	1.54	0.34
P_2S_0	0.73	11.66	3.44	1.03	1.83	0.48
P_2S_1	0.20	38.18	2.78	0.99	1.94	0.50
P_2S_2	0.31	19.09	2.56	1.11	1.96	0.37

Conclusions

The N, P and K contents in stem : root and seed : stem have been found to be varied by the different interaction combinations of P and S applications. The ratios of N, P and K in seed : stem were always higher than that of stem: root suggesting their greater mobility from stem to seed compared to root : stem. The results concluded that the mobility of N, P and K towards seed might be beneficial for maintaining healthy, nutritious and quality seeds vis – a – vis enhancing oil content in rape due to interaction between P and S in soils.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 117-127, 2016

Effect of Integrated Nutrient Management Practices on Important Soil Properties in Terraced Land under Continuous Cultivation of Rice (*Oryza sativa* L.) variety Teke in Nagaland

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Published : 30.10.2017

Abstract

A field experiment was carried out at experimental research farm, Department of Soil and Water conservation, SASRD, Nagaland University. The experiment was maintained for eleven years continuously and local rice variety *Teke* was used for this research evaluation. The soil samples were collected in kharif 2011 from the field to investigate the effect of nutrient management practices on important soil properties in terraced land under continuous cultivation. The experiment was laid down in Randomized Block Design (RBD) with 12 treatments and each treatment was replicated three times. The results revealed that the maximum WHC and hydraulic conductivity was recorded in ½ N+ PK+ ½ N Forest litter with 43.20% and 3.00 cm hr^{-1} while the minimum was recorded in control with 33.20% and 2.30 cm hr^{-1}, respectively. The highest percent aggregates > 0.25 mm and mean weight diameter of the soil was recorded in NPK+ FYM+ Zn with 72.60% and 2.60 mm while the lowest was recorded in control with 53.30% and 1.20 mm, respectively. The highest organic Carbon was recorded in ½N+ PK+ ½N Forest litter with 3.10% and lowest was recorded in control with 1.60%. The highest pH was recorded in Forest litter burned+ ½ FYM with 4.90 and lowest was recorded in NPK and ½N+ PK+ *Azospirillum* with 4.30. The highest CEC was recorded in NPK+ Poultry litter with 24.70 cmol (p^+) kg^{-1} and lowest was recorded in control with 18.20 cmol (p^+) kg^{-1}. In terms of the available NPK, the highest available N and P was recorded in NPK + FYM with 568.40 kg ha^{-1} and 21.90 kg ha^{-1} while the lowest was recorded in control with 310.30 kg ha^{-1} and 8.20 kg ha^{-1}, respectively. Available K was recorded maximum in ½N+ PK+ ½N Forest litter with soil varied from 298.30 kg ha^{-1} and minimum was recorded in control with 143.70 kg ha^{-1}.

Key words : Continuous cultivation, Important soil properties, Nutrient management

Introduction

Integrated Nutrient Management (INM) envisages the use of chemical fertilizers in conjunction with the organic manures, legumes in cropping system, biofertilizers and other locally available sources for sustaining soil health and productivity. Nagaland is a predominantly hilly state occupying an area of 1.65 of which only 11% area is under plain. The rest of the area comprises of mild to steep slopes, rendering the area unsuitable for permanent cultivation without proper management practices. Bench terracing is the most reliable conservation measure frequently employed to manipulate surface topography of hill slopes to convert them to suit intensive agriculture. Bench terracing usually exposes infertile and biologically inert subsoil of less desirable properties for crop growth than those of the top soil (Chauhan, 2001). Consequently, the initial production potential of the terraced land is generally low since the development of soil fertility of the exposed subsoil of terraced fields for sustained production however it is a time taking process. To increase the productivity of terraced land, integrated nutrient management practices should be adopted to ensure a steady build up of soil

fertility together with other properties suitable for plant growth.

Soil fertility development of the resultant surface soil after terracing could be achieved through the addition of manures, fertilizers, bio-fertilizers, organic residues and other amendments either alone or in combinations. The addition of N, P, and K fertilizers with organic sources would increase the availability of plant nutrients and favour accumulation of organic matter on surface soil besides improving soil properties. Soil organic matter also influences a number of physical, chemical and biological properties of the soil and their combined effect together ensures favourable plant growth conditions in soil. Long term manurial treatments have brought about an improvement in soil aggregates and increase availability of N, P and K and grain yield significantly with continuous application of balanced fertilizers and FYM (Mishra and Sharma, 1997). The integrated application of inorganic fertilizers and organic residue would soil fertility and productivity on a sustainable basis since the system would supply almost all the nutrients in judicious way, besides increasing the nutrient use efficiency and improving the physico-chemical properties of the soil.

The data pertaining to the effect of continuous nutrient management practices on soil fertility and performance of upland rice on terraced land in Nagaland is found scanty. Therefore, the present investigation has been conducted to evaluate the effect of integrated nutrient management practices on soil properties and on available N, P and K in terraced land.

Materials and Methods

A long term field experiment was started in 2001 on newly developed bench terraces by the Department of Soil and Water Conservation at the experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland University to study the immediate as well as long term effect of various nutrients management practices on important soil properties of terraced land under rainfed condition. The experiment was maintained for eleven years continuously and local rice variety *Teke* was used for this research evaluation. The soil samples were collected in kharif 2011 from the experimentation field to investigate the effect of nutrient management practices on important soil properties in terraced land under continuous cultivation. The experiment consisted of twelve treatments and replicates three times. The details of the treatment and combinations and the amount of N, P and K added in various treatments each year are given Table 1. A total of 36 plots each having a size of 3.0x 2.0m^2 were used in the experiment.

Field preparation and treatment application

During the 11th year of experimentation, the plots were manually dug three times with spade. The field was then prepared to ensure the good seedbed. The recommended dose of 60 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} for NPK for rice was applied in various treatments (T_2 to T_{11}). The farmyard manure (FYM), poultry litter and forest litter was applied @ 10.0 t ha^{-1}, 3.3 t $ha^{-1}$and 5.0 t ha^{-1}, respectively. The required amount of FYM (T_5), poultry litter (T_7) and forest litter (T_9) to substitute half recommended dose of N (½N; 30 kg ha^{-1}) was worked out based on the N content of these materials and incorporated in soil one month before sowing. Zinc (Zn) was applied @10kg ha^{-1} in the form of $ZnSO_4.7H_2O$ as basal dose. *Azospirillum* was used as a seed treatment before sowing @20g kg^{-1} of seed. Nitrogen was applied as urea in three equal splits at sowing, tillering and panicle initiation stage. The entire doses of P and K (PK) in the form of single super phosphate and muriate of potash, respectively was applied as basal dose. For forest litter burned+ ½FYM treatment (T_{12}) which resembles farmers' practice in Nagaland, the required amount of forest litter @ 5.0 t ha^{-1} was evenly spread on the soil surface and burned there. The ash was incorporated thoroughly in the soil. Thereafter, 5t ha^{-1} of FYM (½FYM) was applied 30 days before sowing and mixed in the soil. All the plots were then finally prepared for sowing. After final preparation of the plots, upland rice (*Oryza sativa* L.) variety 'Teke' was sown on 1st June, 2011 with a spacing of 20cm row to row using a seed rate of 75kg ha^{-1}. The field was maintained weed, pest and disease free during the entire duration of crop growth.

TABLE 1. Amount of N, P and K added during 11 years of cultivation and management both from NPK fertilizers and organic residues

Treatments	Amount of N P K added in 11th year (kg ha^{-1})		
	N	P_2O_5	K_2O
Control: (T_0)	0	0	0
½N+ PK: (T_1)	30	60	40
NPK: (T_2)	60	60	40
NPK+ FYM: (T_3)	110 (60 + 50)	80 (60 + 20)	110 (40 + 50)
½N+ PK+ ½N FYM: (T_4)	60 (30 + 30)	72 (60 + 12)	70 (40 + 30)
NPK+ Poultry litter: (T_5)	110 (60 + 50)	113 (60 + 53)	66 (40 + 26)
½N+ PK+ ½N Poultry litter: (T_6)	60 (30 + 30)	92 (60 + 32)	56 (40 + 16)
NPK+ Forest litter: (T_7)	65 (60 + 5)	62 (60 + 2)	75 (40 + 35)
½N+ PK+ ½N Forest litter: (T_8)	60 (30 + 30)	72 (60 + 12)	250 (40 + 210)
½N+ PK+ *Azospirillum*: (T_9)	30	60	40
NPK+ FYM+ Zn: (T_{10})	110 (60 + 50)	80 (60 + 20)	90 (40 + 50)
Forest litter burned+ ½ FYM: (T_{11})	25	10	25

Note: The figure in the parentheses indicate the amount of N, P_2O_5 and K_2O added through NPK fertilizers and organic residues – FYM, poultry and forest litter.

Collection and preparation of soil samples

Soil samples from individual plots were collected after the harvest of the rice crop and air-dried. Five soil samples from each plot were collected, mixed thoroughly and discarded using quadrat method to retain about 500 g representative soils. Two third of each samples were ground to pass through 2mm sieve and kept in polythene bags for laboratory analysis. The remaining portion of soil samples was preserved for analysis of mean weight diameter and percent aggregation. Undisturbed core soil samples were also collected from each plot to determine bulk density and hydraulic conductivity of the soil.

Soil sample analysis

For the determination of water holding capacity (WHC), soil sample were packed in Keen Rackzowaski boxes with uniform tapping and saturated overnight. After saturation the samples were weighed and kept in oven for 48 hours at equilibrium temperature of 105^{0}C. The samples were then cooled and weighed. The water holding was calculated by the weight difference (Piper, 1966). Summation of all the fractions > 0.25 mm in wet sieving gave percent macro-aggregates. For the determination of Mean weight diameter (MWD), air-dried natural clod samples were broken into gentle pressure and passed through 8 mm mesh sieve and retained on 5 mm sieve. Fifty grams of soil retained on 5 mm mesh sieve were transferred on the topmost sieve of the nest of the sieves arranged in the order of 5, 2, 1, 0.5 and 0.25 mm, respectively. The nest of the sieves was then emerged under water for 30 minutes in Yoder's apparatus for 30 minutes. Fractions retained in each sieve was collected, oven dried at equilibrium temperature for 24 hours, weighed and percent aggregation (of various sizes) was calculated. MWD was then calculated from the equation given by Van Bavel (1949). The particle density of the soil was determined by the pycnometer

method and the bulk density of the soil was determined by the core method as described by Baruah and Barthakur (1997). Saturated hydraulic conductivity was then calculated from Darcy's equation as cited by Baruah and Barthakur (1997). Organic carbon was determined by the Wet Digestion Method of Walkley and Black as described by Jackson (1973). Soil pH was determined in 1:2.5 soil water suspension using glass electrode pH meter. The cation exchange capacity (CEC) of NH_3 distillation method (Jackson 1973). The available N content of the soil was estimated by the alkaline permanganate method of Subbiah and Asija (1956). The available P in soil was extracted by Bray's method No.1 (Brays and Kurtz, 1945). The available potassium was determined by flame photometer after extracting the soil with neutral normal ammonium acetate (pH 7.0) (Jackson, 1973). The available K was extracted from the soil with neutral normal ammonium acetate (Jackson, 1973) and estimated flame photometrically.

All the data's collected were subjected to one way analysis of variance (ANOVA) by Randomized Block Design (RBD) and each treatment was replicated three times. Fisher Shedecor 'F' test was used to determine the significance and non-significance of the variance due to different treatments at 0.05 level of significance.

Results and Discussion

Effect of integrated nutrient management practices on physical properties of soil under continuous cultivation

Water holding capacity (WHC)

After eleven years of continuous addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations showed a significant increase in WHC in all the treatments except in ½N+ PK, NPK and Forest litter burned+ ½ FYM treatments over control (Table 2). The maximum WHC was recorded in ½ N+ PK+ ½ N Forest litter with 43.20% and minimum was recorded in control with 33.20%. The WHC recorded in NPK+ FYM, NPK+ Poultry litter, NPK+ FYM+ Zn was at par and increased significantly as compared to NPK. Further, WHC recorded in NPK+ Poultry litter and NPK+ FYM+ Zn had significant increase over NPK+ Forest litter. The WHC in ½ N+ PK, NPK, ½ N+ PK+ *Azospirillum* and Forest litter burned+ ½ FYM was found to be par. The increase in water holding capacity of the soil with integrated application of inorganic fertilizers with organic sources might be related to both the increase in organic matter content of the soil and improvement in its physical properties. These findings are in accordance with the findings reported by other workers (Laxminarayana 2006 and Singh *et al*., 2006) reported that the application of organic manures either alone or in combinations with inorganic fertilizers progressively improved the water holding capacity of the soil.

Percent aggregation

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in aggregates > 0.25 mm in all the treatments except in ½ N+ PK over control (Table 2). The highest percent aggregates > 0.25 mm was recorded in NPK+ FYM+ Zn with 72.60% while the lowest was in control with 53.30%. The aggregates > 0.25 mm in NPK+ FYM, NPK+ Poultry litter and NPK+ FYM + Zn was at par and showed a significant increase over NPK. Further aggregates > 0.25 mm in ½ N+ PK+ ½ N Poultry litter and ½ N+ PK + ½ N Forest litter was at par with ½ N+ PK + ½ N FYM but showed a significant increase as compared to NPK. The increase in percent aggregates in NPK+ FYM+ Zn, NPK+ FYM, NPK+ Poultry litter and NPK+ Forest litter over NPK was 11.20%, 10.90%, 9.10% and 6.10%, respectively. The higher percent aggregation in these treatments might be because of higher organic matter content in these treatments that together with clay and other soil constituents favour particle aggregation. These findings are in accordance with the findings reported by Bellakki *et al.* (1998); and Nambiar and Ghosh (1984). Selvi *et al*. (2003) also reported that application of FYM along with NPK fertilizers caused significant increase in the water stable aggregates.

TABLE 2. Effect of integrated nutrient management practices on physical properties of soil under continuous cultivation

Treatments	C (%)	WH	gates > 0.25mm (%)	Aggre	Mean n weight diameter (mm)	Particle density (g cm^{-3})	Bulk density (g cm^{-3})	Hydraulic conductivity (cm hr^{-1})
Control: (T_0)	0	33.2	53.30		1.20	2.10	1.38	2.30
½N+PK:(T_1)	0	34.5	57.40		1.80	2.10	1.34	2.40
NPK: (T_2)	0	35.0	65.30		1.90	2.10	1.36	2.40
NPK+ FYM: (T_3)	0	40.3	72.40		2.50	2.00	1.24	2.90
½N+ PK+ ½N FYM: (T_4)	0	39.3	69.30		2.20	1.90	1.26	2.80
NPK+ Poultry litter: (T_5)	0	42.3	71.30		2.30	2.00	1.23	2.70
½N+ PK+ ½ N Poultry litter: (T_6)	0	40.5	70.30		2.40	1.90	1.27	2.70
NPK+ Forest litter: (T_7)	0	38.7	69.30		2.00	2.20	1.25	2.90
½N+ PK+ ½N Forest litter: (T_8)	0	43.2	72.30		2.50	2.10	1.17	3.00
½N+ PK+ *Azospirillum*: (T_9)	0	37.0	68.20		1.90	2.00	1.28	2.60
NPK+ FYM+ Zn: (T_{10})	0	42.0	72.60		2.60	2.00	1.23	2.90
Forest litter burned+ ½ FYM: (T_{11})	0	35.7	64.10		1.80	2.10	1.32	2.50
SEm ±		1.09	1.68		0.12	-	0.04	0.06
CD (P=0.05)		3.22	4.97		0.37	NS	0.12	0.18

Mean weight diameter (MWD) of soil

The mean weight diameter of soil in all the treatments showed a significant increase over control (Table 2). The highest MWD was recorded in NPK+ FYM+ Zn with 2.60 mm and the lowest was in control with 1.20 mm. The MWD in NPK+ FYM+ Zn, NPK+ FYM and NPK+ Poultry litter was at par and showed a significant increase over NPK. The MWD in ½ N+ PK+ ½ N Poultry litter and ½ N+ PK+ ½ N Forest litter was at par with ½ N+ PK+ ½ N FYM but showed a significant increase over NPK. However, MWD in NPK, Forest litter burned+ ½ FYM and ½N+ PK was at par to each other. The significant increase in MWD in NPK+ FYM, NPK+ Poultry litter, NPK+ FYM+ Zn, ½N+ PK+ ½N Poultry litter and ½N+ PK+ ½N Forest litter treatments was higher over NPK with 31.50, 21.10, 36.80, 26.30, and 31.60%, respectively. The higher MWD in these integrated treatments might be due to higher percent aggregates in these treatments as compared to NPK.

Particle density

The highest particle density was recorded in NPK + Forest Litter with 2.20 g cm^{-3} and the lowest was recorded in ½N+ PK+ ½N FYM and ½N+ PK+ ½N Poultry litter with 1.90 g cm^{-3} each (Table 2). The particle density did not show any variation after eleven years of continuous cultivation and nutrient management. However particle density in ½N+ PK, NPK, Forest litter burned+ ½ FYM, NPK+ Forest litter and ½N+ PK+ ½N Forest litter treatments were comparatively higher than other treatments.

Bulk density

The data revealed that NPK with poultry litter, forest litter and FYM + Zn had a significant decrease in bulk density over control (Table 2). The maximum bulk density was recorded in control with 1.38 g cm^{-3} and minimum was recorded in ½N+ PK+ ½N Forest litter with 1.17 g cm^{-3}. The bulk density of NPK + FYM and NPK + Forest litter was at par with NPK. The bulk density in NPK + Poultry litter and NPK + FYM + Zn was significantly lower than NPK. The bulk density in ½ N + PK + ½ N Forest litter decreased significantly as compared to NPK. These might be because of the higher levels of organic C content in these treatments. Bajpai *et al*. (2006) also reported that application of green manure, FYM or crop residue as a substitute of N reduced the bulk density significantly.

Hydraulic conductivity

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in hydraulic conductivity in all the treatments except in NPK and ½N+ PK treatments over control (Table 2). The maximum hydraulic conductivity was recorded in ½N+ PK+ ½N Forest litter with 3.00 cm hr^{-1} and minimum was recorded in control with 2.30 cm hr^{-1}. The hydraulic conductivity of NPK + Forest litter, NPK + FYM and NPK + FYM + Zn was at par and had significant increase over NPK and NPK + Poultry litter. The data established that addition of NPK in combination with FYM, poultry litter or forest litter increased the hydraulic conductivity significantly. The significant increase in hydraulic conductivity in these treatments might be due to increase in organic matter content and resultant increase in the porosity of the soil. Similar observations were also made by Bellakki *et al*. (1998). Babhulkar *et al*. (2000) reported that the bulk density of the soil under combined application of fertilizers and FYM decreased as compared to other treatments resulting in significant increase in hydraulic conductivity.

Effect of integrated nutrient management practices on chemical properties of soil under continuous cultivation

Organic carbon

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in organic C content in all the treatments over control (Table 3). The highest organic C was recorded in ½N+ PK+ ½N Forest litter with 3.10% followed by NPK+ FYM, NPK+ FYM+ Zn, NPK+ poultry litter and ½ N + PK + ½ N Poultry litter with 2.90%, 2.80%, 2.80% and 2.70%, respectively and lowest was recorded in control with 1.60%. The data revealed that integrated addition of inorganic fertilizers with organic

sources in any combinations favored significantly higher build up in organic C as compared to other treatments. Among treatments receiving half N from fertilizer and other half from organic sources, a significant build up in organic C was recorded in ½N+ PK+ ½N Forest litter and ½N+ PK+ Poultry litter treatments over NPK. The increases in organic C content in soil on addition of organic sources have been reported by earlier workers (Laxminarayana and Patiram, 2006; Surekha *et al*., 2004; Chauhan and Game, 2002). Similarly, Humtsoe and Chauhan (2005) also reported maximum organic C content in Alder litter incorporated followed by NPK+ FYM and surface soil+ FYM treatments. The significant increase in organic C in integrated treatments combining inorganic fertilizers either with forest litter, poultry litter or FYM may be because of the combine effect of the amount of the organic residues C added and its nutrient content, plant residue C return to the soil and efficiency of microbial population in utilizing added organic C.

Soil pH

The addition of NPK alone or in combination with FYM continuously for eleven years caused a significant decrease in pH over control (Table 2). Addition of ½N+ PK+ ½N FYM, and ½N+ PK+ ½N Forest litter and Forest litter burned+ ½ FYM brought about a significant increase in pH over NPK. The highest pH was recorded in Forest litter burned+ ½ FYM with 4.90 followed by NPK+ Forest litter and ½N+ PK+ ½N Forest litter with 4.70 each and lowest was recorded in NPK and ½N+ PK+ *Azospirillum* with 4.30.

The reduction in soil pH on addition of N fertilizers has been well established. The significant decrease in soil pH on addition of NPK fertilizer alone by 0.30 units over control are in accordance with those reported by Humtsoe and Chauhan (2005), Kumar and Yadav (1993), Sharma *et al*. (1988) and Minhas and Mehta (1984). Integrated application of NPK with poultry litter or forest litter, and addition of ½N+ PK+ ½N FYM and ½N+ PK+ ½N Forest litter caused a significant increase of 0.20 to 0.40 units in soil pH as compared to NPK. Significant increase in soil pH on addition of Forest litter burned + ½ FYM are in accordance with those reported by Humtsoe and Chauhan (2005).

Cation exchange capacity (CEC)

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in CEC in all the treatments except in ½N+ PK and Forest litter burned+ ½ FYM treatments over control (Table 3). The highest CEC was recorded in NPK+ Poultry litter with 24.70 cmol (p^+) kg^{-1} and lowest was recorded in control with 18.20 cmol (p^+) kg^{-1}. The CEC in NPK+ FYM+ Zn, NPK+ Poultry litter, NPK+ Forest litter and NPK+ FYM was at par and showed a significant increase over NPK. The data revealed that addition of NPK+ Poultry litter, NPK+ FYM+ Zn and NPK+ FYM caused significant increase of 16.50%, 14.60% and 10.80% in CEC as compared to NPK alone. The increase in humus content on decomposition of added organic sources may be responsible for increasing the negative charge on the organic colloid of the soil, which in turn would contribute to increase in CEC of the soil. Selvi *et al*. (2003) and Babhulkar *et al*. (2000) also reported that application of NPK fertilizers along with FYM or organic residues caused significant increase in CEC of soil. The decrease in CEC in NPK and ½N+ PK treatments may be the result of continuous application of only chemical fertilizers without organic sources over a long period of time. This is in conformity with the findings of Nambiar and Ghosh (1984) who reported that continuous application of chemical fertilizer caused a decrease in calcium saturation and CEC of soil. Prasad *et al*. (1983) also reported that 6 years of continuous application of chemical fertilizer resulted in a decrease in CEC on a red loam soil of Ranchi.

Availability of N, P and K of the soil under continuous cultivation

Available N of the soil

The data showed that continuous application of fertilizer, FYM, poultry litter, forest litter

Table 3. Effect of integrated nutrient management practices on chemical properties of soil under continuous cultivation

Treatments	Organic C (%)	pH	CEC [cmol (p^+) kg^{-1}]
Control: (T_0)	1.60	4.60	18.20
½N+ PK: (T_1)	2.20	4.60	18.70
NPK: (T_2)	2.40	4.30	21.20
NPK+ FYM: (T_3)	2.90	4.40	23.50
½N+ PK+ ½N FYM: (T_4)	2.40	4.50	21.40
NPK+ Poultry litter: (T_5)	2.80	4.50	24.70
½N+ PK+ ½N Poultry litter: (T_6)	2.70	4.40	23.40
NPK+ Forest litter: (T_7)	2.60	4.70	22.60
½N+ PK+ ½N Forest litter: (T_8)	3.10	4.70	23.10
½N+ PK+ *Azospirillum*: (T_9)	2.50	4.30	23.30
NPK+ FYM+ Zn: (T_{10})	2.80	4.40	24.30
Forest litter burned+ ½ FYM: (T_{11})	2.30	4.90	18.60
SEm ±	0.098	0.057	0.72
CD (P=0.05)	0.29	0.17	2.13

and *Azospirillum* in different combinations caused a significant increase in available N in all the treatments except in Forest litter burned + ½ FYM (Table 4). Among different treatments, highest available N was recorded in NPK + FYM with 568.40 kg ha^{-1} and lowest available N was recorded in control with 310.30 kg ha^{-1}. The available N content in NPK + FYM, NPK + FYM + Zn and NPK + Poultry litter was at par and showed a significant increase over NPK and NPK + Forest litter treatments. The data revealed that addition of NPK or integrated application of both inorganic and organic sources in different combinations caused as significant build up in available N in soil as compared to control. The significant increase in available N content in soil on addition of NPK fertilizers, FYM, poultry litter, forest litter and other amendments in different combinations to upland rice are in agreement with those reported by other workers (Bajpai *et al.*, 2006 and Mahala *et al.*, 2006).

The significant increase in available N content in NPK+ Poultry litter, NPK+ FYM and NPK+ FYM+ Zn over NPK+ Forest litter and NPK might be due to the variations in the build up of the available N constituents in these treatments. Laxminarayana (2006) also observed a significant increase in available N content in NPK+ Poultry litter and NPK+ FYM over NPK after three years of continuous cropping and nutrient management. Imtilemla *et al.* (2009) also observed that addition of fertilizer alone or in combinations with FYM, poultry litter, forest litter and also with *Azospirillum* resulted in an increase in available N content in the soil on terraced land under continuous cultivation of rice for five years.

TABLE 4. Effect of integrated nutrient management practices on Availability of N, P and K of soil under continuous cultivation

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Control: (T_0)	310.30	8.20	143.70
½N+ PK: (T_1)	330.50	13.60	180.20
NPK: (T_2)	363.70	18.50	183.30
NPK+ FYM: (T_3)	568.40	21.90	267.30
½N+ PK+ ½N FYM: (T_4)	451.50	20.30	233.70
NPK+ Poultry litter: (T_5)	557.80	20.40	265.30
½N+ PK+ ½N Poultry litter: (T_6)	480.10	19.30	260.20
NPK+ Forest litter: (T_7)	380.30	18.80	241.40
½N+ PK+ ½N Forest litter: (T_8)	475.20	17.50	298.30
½N+ PK+ *Azospirillum*: (T_9)	480.30	18.00	204.50
NPK+ FYM+ Zn: (T_{10})	565.30	21.20	269.80
Forest litter burned+ ½ FYM: (T_{11})	325.40	10.60	188.70
SEm ±	5.25	0.92	5.61
CD (P=0.05)	15.47	2.73	16.52

Available P of the soil

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in available P content in all the treatments except in Forest litter burned+ ½ FYM over control (Table 4). The highest available P was recorded in NPK + FYM with 21.90 kg ha^{-1} and lowest was recorded in control with 8.20 kg ha^{-1}.

The data revealed that relatively higher available P levels accumulated in treatments where NPK fertilizers were applied in combinations with poultry litter and FYM. A marginal increase in available P was found in Forest litter burned+ ½ FYM. These results are in accordance with those reported by Chauhan and Game (2002) and Humtsoe and Chauhan (2005). These investigators reported that continuous nutrient management of soil with fertilizers, manures and other soil amendments alone or in combinations on a terraced land showed increased available P content in soil except that of Alder litter incorporated and burned. Laxminarayana (2006) reported highest available P (12.15 kg ha^{-1}) with the application of 100% NPK+ Poultry manure. Singh *et al*. (2008) also reported that available P content of surface soil increased appreciably with the application of manures along with fertilizers as compared to sole application of NPK fertilizers.

Available K of the soil

The data showed that continuous application of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations for eleven years caused a significant increase in available K content in all the treatments (Table 4). The maximum available K was recorded in ½N+ PK+ ½N Forest litter with soil varied from 298.30 kg ha^{-1} and minimum was recorded in control with 143.70 kg ha^{-1}. The available K content in NPK+ FYM, NPK + poultry litter and NPK+ FYM+ Zn was at par and showed a significant

increase over NPK+ Forest litter and NPK treatments.

The data established that addition of NPK in combination with FYM, poultry litter or forest litter increased the available K content significantly. These results corroborate the findings of other workers (Mathur, 1997; Humtsoe and Chauhan, 2005; Singh *et al*., 2006). The significant increase in available K content in the treatments receiving half N from fertilizer in combination with other half from FYM, poultry litter and forest litter suggested that ½N+ PK+ ½N Forest litter, ½N+ PK+ ½N Poultry litter and ½N+ PK+ ½N FYM treatments could preferably be used to build up available K levels in soil even in situation where fertilizers are adequately available. Tolanur and Badanur (2003) also observed significant increase in available K content of the surface soil with the application of 50% N through organic manure in conjunction with 50% recommended dose of fertilizer under pearl millet-pigeon pea cropping system.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 129-132, 2016

Seed Potentiation of a Green Gram Species Under Storage

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Published : 30.10.2017

Abstract

Green gram (*Phaseolous mungo* L.) seeds lost viability at a rapid pace under accelerated ageing condition. Pretreatment of the seeds with leaf extracts of bel (*Aegel marmelos*) and tulsi (*Ocimum sanctum*) 25g in 1000 ml distilled water of each for 4 hours before accelerated ageing treatment (100% RH and 30±2°C) for different durations for 30 days under the accelerated ageing condition slowed down the ageing-induced rapid loss of seed germination and reduced the time required for 50% seed germination (T_{50}) of the seed species. The leaf extracts also arrested the reduction of protein, insoluble carbohydrate and DNA levels as well as activity of catalase enzyme of seed kernels during forced ageing period. The promising effect of experimental plant extracts on enhancement of seed potential of a green gram species was recorded in this investigation.

Key Words : Green gram, accelerated ageing, bel, tulsi, seed potentiation.

Introduction

High temperature and high relative humidity (RH) during the major part of a year in Indian agro-climatic condition is a major problem for seed storage and greatly accelerate seed ageing phenomenon causing consequent deterioration and non-viability of seeds (Basu, 1994; Pati and Bhattacharjee, 2013; Bakali, 2015). As most crop seeds require storage for either one or several planting seasons, agriculturists and horticulturists particularly in the West Bengal State of India are often handicapped with respect to maintenance of standard seed vigour under ambient storage environment (Basu, 1994). Keeping this problem of seed germination in mind, an attempt was made in this investigation for the retention of the seed viability and enhancement of storage potential of a green gram species having viability problem. Present experiment was performed under accelerated ageing condition by imposing 100% RH with a view to maintaining the adverse storage condition and also to obtain expeditious results. In fact, accelerated ageing treatment provides a powerful manipulative tool which makes it possible to study the process of seed deterioration over a very short period and this mimics the natural ageing process (Heydecker, 1972; Pati and Bhattacharjee, 2016).

Thus, the major objective of this work was to test the efficacy of the leaf extracts of bel (*Aegel marmelos*) and tulsi (*Ocimum sanctum*) on the enhancement of seed potential of a green gram species.

Materials and Methods

After surface sterilization (0.1% $HgCl_2$ for 90 seconds) the seeds of green gram (*Phaseolous mungo* L.) was separately presoaked in the aqueous solutions of leaf extracts of bel (*Aegel marmelos*) and tulsi (*Ocimum sanctum*) 25g in 1000 ml distilled water of each for 4 hours and then dried back to the original dry weight of the seeds. The pretreated seed lots were taken in separate porous cloth bags and thus stored in a desiccator in which 100% relative humidity (RH) was preimposed by keeping distilled water within it. This experimental set-up was kept at 30±2°C for 30 days allowing the seeds to experience forced ageing treatment and distilled water was changed at 15 day intervals to restore the desired RH within the desiccators for 30 days.

From the seed lots germinability capacity of seeds was made after 0, 15 and 30 days of accelerated ageing treatment. To analyse the percentage germination, 100 seeds of each group were transferred to separate Petri dishes containing filter paper moistened with distilled water. Germination data was recorded after 96 hours of seed soaking following the International Rules for Seed Testing, 1976 .The time for 50% germination (T_{50}) was determined following the method described by Coolbear *et al*., 1984. Protein, insoluble carbohydrate and DNA levels of seed kernels were estimated following the method of Lowry *et al.,*1951;McCready *et al.*,1950 and Cherry,1962 modified by Choudhuri and Chattarjee,1970 respectively. Extraction and estimation of the enzyme catalase was made following the method of Snell and Snell, 1971. Assaying of the enzyme was done as per the method of Fick and Qualset, 1975.

All the data were statistically analysed at the treatment and replication levels and least significant difference (LSD) values were calculated at 95% confidence limits as per Panse and Sukhatme (1967).

Results and Discussion

The pretreating plant extracts significantly alleviated the accelerated ageing-induced loss of germination and reduced T_{50} hours (Table 1), arrested the reduction of protein and insoluble carbohydrates (Table 2), DNA and activity of catalase enzyme (Table 3). Reduced seed germinability is considered to be the important visible criteria for the evaluation of poor seed vigour (Anderson, 1970; Halder *et al*., 1983; Rai, 2000). In this investigation, the plant extracts-induced arrestation of loss of seed germination is the indicative of retention of seed viability property of the experimental plant extracts.

Loss of some vital cellular components occurred during the process of seed deterioration are available in literature (Abdul-Baki and Anderson, 1972; Kole and Gupta, 1982; Bakali, 2015). Catalase (Abdul-Baki and Anderson 1972, Yadav *et al.* 2003) activity is generally used as very reliable indices for the evaluation of seed viability. High level of catalase activity in high vigour seeds have also been reported (Pati and Bhattacharjee, 2015). So, from the present observations of higher metabolic status of the leaf extracts of bel (*Aegel marmelos*) and tulsi (*Ocimum sanctum*) pretreated green gram seeds, it seems quite apparent that the seed pretreating agents considerably hardened the seeds and such hardening is effected at the metabolic level which subsequently resulted in retention of seed vigour and consequent extension of seed viability as well as enhancement of seed potential.

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TABLE 1. Effect of seed pretreatment with leaf extracts of *Aegel* sp. and *Ocimum* sp. (25g/1000ml each) on percentage seed germination and T_{50} (time required for 50% germination) values of green gram seeds.

Seeds were presoaked with the plant extracts or distilled water for 4h and then dried back to original seed weight. This was repeated twice. Pretreated seed samples were kept under 100% RH and data were recorded after zero (0), 15 and 30 days of accelerated ageing.

Seed species	Treatments	Percentage of germination			T_{50} of germination (h)		
		Days after accelerated ageing					
		0	15	30	0	15	30
	Control	100.00	90.00	45.08	42.70	52.00	NA
Green	*Aegel* sp.	100.00	95.00	52.08	35.30	45.00	70.00
gram	*Ocimum* sp.	100.00	96.00	54.16	34.84	47.00	60.00
	LSD (P=0.05)		NC	4.10	2.06	1.11	1.10

3.00

NC: Not calculated; NA: Non attainment of 50% germination.

TABLE 2. Effect of seed pretreatment with leaf extracts of *Aegel* sp. and *Ocimum* sp. (25g/1000ml each) on protein (mg/g fresh weight) and insoluble carbohydrate (mg/g fresh weight) level in seed kernels of green gram seeds.

Treatments and recording of data as in Table 1.

Seed species	Treatments	Protein			Insoluble carbohydrate		
		Days after accelerated ageing					
		0	15	30	0	15	30
	Control	260.70	210.00	105.21	300.10	270.53	120.84
Green	*Aegel* sp.	260.80	248.10	120.03	300.12	288.09	167.58
gram	*Ocimum* sp.	260.90	248.20	122.80	300.11	288.26	166.60
LSD (P=0.05)		NS	2.01	6.72	NS	2.10	1.80

NS: Not significant

TABLE 3. Effect of seed pretreatment with leaf extracts of *Aegel* sp. and *Ocimum* sp. (25g/1000ml each) on DNA (mg /g fresh weight) and the activity of the enzyme catalase (ΔOD×Tv/txv) in seed kernels of green gram seeds.

Seed species	Treatments	DNA			Catalase		
		Days after accelerated ageing					
		0	15	30	0	15	30
	Control	65.21	40.74	23.00	42.40	32.09	21.00
Green	*Aegel* sp.	65.52	51.00	30.95	42.37	39.07	32.31
gram	*Ocimum* sp.	65.48	51.28	31.21	42.18	39.02	33.01
	LSD (P=0.05)	NS	2.05	1.01	NS	1.14	1.15

NS: Not significant

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 133-139, 2016

Potassium Status in Some Entisols, Inceptisols and Alfisols of West Bengal

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Published : 30.10.2017

Abstract

The distribution of various forms of K and their relations with physical and chemical properties of thirty five surface (0-0.15 m) soils belonging to entisols, Inceptisols and Alfisols were investigated. The water soluble, exchangeable, available, non-exchangeable and lattice K ranged from 5.8-34.4, 50.3-256.1, 59.5-288.2, 322-2540 and 997-7820; 5.0-38.2, 58.5-324.5, 63.5-362.7, 382-1880 and 1229-5930; 5.1-17.4, 55.3-141.5, 68.5-155.0, 312-1620 and 957-5180 mg kg^{-1} for Entisols, Inceptisols and Alfisols, respectively. Inceptisols followed by Entisols showed relatively higher values of all forms of soil K. Water soluble K had significant positive correlation with sand and EC and significant negative correlation with clay. Non-exchangeable and lattice K had highly significant negative correlation with sand and significant positive correlation with clay. Water soluble K showed high significant positive correlations with exchangeable K and significant negative correlations with non-exchangeable K and lattice K. There was strong significant positive correlation between non-exchangeable K with lattice K.

Key words : alfisols, entisols, inceptisols, potassium

Introduction

The importance of potassium nutrition to plants in Indian agriculture is increasing with passage of time as a result of modern explosive agriculture with less attention in K fertilizer administration. The knowledge about the nature and quantity of different forms of soil K and the conditions controlling its availability to crops is important for the appraisal of the available potassium status of the soil. The equilibrium between solution K and exchangeable K occurs rapidly, but that of exchangeable K and non-exchangeable K happens very slowly (Ghiri *et al*., 2010). Potassium transmission from mineral fraction to any of the other three forms is extremely slow in most soils (Havlin *et al*., 1999). The long-term experimental results have established the greater and prominent role of non-exchangeable K to potassium nutrition to plants (De *et al*., 1993, Patra and Debnath, 1996; Setia and Sharma, 2004; Patra *et al.* 2008). Thus the total quantity and the relative abundance of various forms of K greatly influence the K supplying capacity of soil and potassium nutrition to crops. The availability of K to plants depend largely on soil and clay minerals characteristics, climates and cropping (Pal and Mukhopadhyay, 1992; Ghosh and Mukhopadhyay, 1997; Patra *et al*., 2001). Thus an overall knowledge of the relationship of different forms of K among themselves and with the physicochemical properties of the soils helps to predict the K availability to plants and formulating a proper K fertilizer schedule for better crop nourishment and K use efficiency. The present study is undertaken to assess the distribution of various forms of K in some Entisols, Inceptisols and Alfisols of West Bengal and their relationships with relevant soil characteristics as well as the forms of potassium.

Materials and Methods

Thirty five surface (0-0.15 m) soil samples belonging to Entisols, Inceptisols and Alfisols were collected from ten districts covering different agro-ecological situations under intensive rice-based cropping system in West Bengal (Table 1). Soil samples

Table 1. Mechanical composition of some great group soils of West Bengal

Location of the soil	District	Great group	Sand (%)	Silt (%)	Clay (%)	Textural class
Patchhara	Coochbehar	Psammaquent	61.8	18.2	20.0	scl
Shilkhuribos	Coochbeha	Fluvaquent	64.0	20.0	16.0	sl
Daluadashgir	Coochbeha	Haplaquent	73.2	14.3	12.5	sl
Bhogramguri	Coochbeha	Ustifluvent	62.0	20.0	18.0	sl
Berhampore	Murshidabad	Fluvaquent	57.4	26.1	16.5	sl
Golahat	Murshidabad	Fluvaquent	63.3	14.4	22.3	scl
Gayeshpur	Nadia	Fluvaquent	55.6	21.3	23.1	scl
Duttaphulia	Nadia	Ustifluvent	29.9	24.4	45.7	cl
Gayeshpur	Nadia	Fluvaquent	55.3	11.5	33.2	scl
Memari	Burdwan	Haplaquent	44.3	30.2	25.5	l
Rangamati	Birbkum	Ustifluvent	70.0	12.0	18.0	sl
Mandaron	Hooghly	Haplaquent	59.3	20.1	20.6	scl
Sonamukhi	Bankura	Ustochrept	56.7	21.9	21.4	scl
Molebona	Bankura	Ustochrept	49.3	30.2	20.5	l
Piparjhori	Bankura	Ustochrept	71.5	12.1	16.4	sl
Bishnupur	Bankura	Ustochrept	53.6	14.3	32.1	scl
Joyrambati	Bankura	Ustochrept	24.9	37.5	37.6	cl
Benechapra	Bankura	Ustochrept	65.1	11.2	23.7	scl
Mondouri	Nadia	Haplaquept	24.7	55.5	19.8	sil
Jaguli	Nadia	Haplaquept	24.1	40.0	35.9	cl
Barabelu	Hooghly	Haplaquept	62.0	10.0	28.0	scl
Kamarpukur	Hooghly	Fluvaquept	55.5	11.9	32.6	scl
Hoera	Hooghly	Haplaquept	33.3	35.8	30.9	cl
Dharmadanga	Malda	Endoaquept	63.5	16.4	20.1	scl
Sonamukhi	Birbhum	Ustochrept	54.1	28.2	17.7	sl
Manidaha	Medinipur	Endoaquept	71.0	11.6	17.4	sl
Beniasol	Purulia	Ustochrept	60.0	10.0	30.0	scl
Nanduara	Purulia	Ustochrept	24.9	37.5	37.6	cl
Chorchitta	Bankura	Haplustalf	73.6	12.9	13.5	sl
Kajladaha	W. Medinipur	Haplustalf	66.0	22.3	11.7	sl
Sainthia	Birbhum	Haplustalf	42.0	34.0	24.0	l
Kotasur	Birbhum	Haplustalf	58.0	12.5	29.5	scl
Bolpur	Birbhum	Endoaqualf	50.0	16.0	34.0	scl
Bishpuria	Purulia	Haplustalf	65.7	12.1	22.2	scl
Sindarpatti	Purulia	Haplustalf	44.5	30.1	25.4	l

scl: sandy clay loam, sl: sandy loam, sil: silt loam, l: loam, cl: clay loam

were air-dried, ground to pass through a 2 mm sieve and analyzed for particle size, organic carbon, pH, electrical conductivity, CEC, available nitrogen and phosphorus by standard methods (Jackson, 1973). HCl extractable or lattice K was determined according to the AEA method (Piper, 1966) and fixed or non-exchangeable K with boiling 1N HNO3 (Wood and DeTurk, 1941). Available K was extracted with neutral 1N NH4OAc (Jackson, 1973) and water soluble K with distilled water (Grewal and Kanwar, 1966). The exchangeable K was calculated by subtracting water soluble K from available K. Potassium in the extract was measured by flame photometer. The correlation and regression analysis were worked out by using SPSS-7.5 software.

Results and Discussion

Physicochemical characteristics of soils

The soils were sandy loam to sandy clay loam in texture with clay, silt and sand varied from 11.7 to 45.7, 10.0 to 55.5 and 24.1 to 73.6 percent, respectively (Table 1). Soil pH ranged between 4.52 and 7.82 indicating very strongly acidic to mildly alkaline in reaction (Table 2). The electrical conductivity of soils varied widely from 0.03 to 0.69 dS m^{-1}, while organic C contents and CEC of soils ranged between 2.13 to 9.49 g kg^{-1} and 11.8 to 18.1 cmol (p^{+}) kg^{-1}, respectively. Available nitrogen and phosphorus contents of soils were in the limit of 74.1 to 337.4 and 13.9 to 65.7 kg ha^{-1}, respectively.

Forms of soil potassium

The water soluble K was within the limit of 5.0 to 38.2 with a mean value of 16.6 mg kg^{-1} soil (Table 3). The corresponding values were 5.8-34.4, 5.0-38.2 and 5.1-17.4 mg kg^{-1} soil with an average of 18.8, 16.4 and 13.6 mg kg^{-1} soil for Entisols, Inceptisols and Alfisols, respectively. Among the various forms of potassium, water soluble K was the least dominant fraction. This constituted an average of 13.0 per cent towards available K and 1.84 per cent towards non-exchangeable K. The low concentration of water soluble K in soils is due to the combined effect of crop removal and leaching losses (Patra and Debnath, 1996).

The exchangeable K contents of the soils ranged between 50.3 and 324.5 with an average of 110.7 mg kg^{-1} (Table 3). The corresponding values were 50.3-256.1, 58.5-324.5 and 55.3-141.5 mg kg^{-1} with a mean value of 110.9, 118.1 and 93.4 mg kg^{-1} for Entisols, Inceptisols and Alfisols, respectively. This K fraction, on an average, contributed 87.0 per cent towards available K and that of 12.3 per cent towards non-exchangeable K. This form is specifically adsorbed on the exchange sites of soil clay complex. The higher concentration of exchangeable K in soils could be attributed to the addition of K through plant residues, manures and fertilizers.

The available K status (neutral normal NH_4OA_C extractable) of the soils varied from 59.5 to 362.7 with an average of 127.3 mg kg^{-1} (Table 3). The corresponding values were 59.5-288.2, 63.5-362.7 and 68.5-155.0 mg kg^{-1} with a mean value of 129.7, 134.4 and 107.0 mg kg^{-1} for Entisols, Inceptisols and Alfisols, respectively. This fraction of K, on an average, constituted 14.1 per cent of non-exchangeable K. Based on the rating chart proposed by Datta *et al.* (1966), 13 soils were low, 18 soils were medium and remaining 4 soils were high in available K status. The variation in available K content in the soils may be attributed to differential release of K from non-exchangeable and lattice K as well as variation in labile pool due to potassium fertilization.

The non-exchangeable K contents of the soils varied within a range of 312 to 2540 with a mean value of 899 mg kg^{-1} (Table 3). These values were 322-2540, 382-1880 and 312-1620 mg kg^{-1} with an average of 796, 1010 and 825 mg kg^{-1} for Entisols, Inceptisols and Alfisols, respectively. According to the rating charts proposed by Subba Rao *et al.* (1993), 13 soils were medium, 13 soils were high and the remaining nine soils were rated as very high category. This form of reserve soil K is considered to be slowly available to plants over a longer period of time under K-stress situation especially when the level of solution and exchangeable K are depleted by plant uptake and leaching losses (Subba Rao *et al.,* 1993).

The lattice K or structural component of reserve K of the soils varied from 957 to 7820 with an average

Table 2. Physicochemical and chemical characteristics of the experimental field soils

Location of the soil	pH (1:2.5)	EC (dSm^{-1})	Organic C ($g\ kg^{-1}$)	CEC ($cmolkg^{-1}$)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)
Patchhara	5.87	0.32	6.50	12.83	118.8	34.5
Shilkhuribos	7.80	0.42	4.70	16.40	124.5	26.9
Daluadashgir	6.75	0.35	4.58	11.20	115.3	37.2
Bhogramguri	6.80	0.40	5.50	14.30	111.6	34.7
Berhampore	5.34	0.19	3.10	8.20	119.8	51.5
Golahat	6.16	0.24	4.40	9.40	122.9	45.2
Gayeshpur	6.10	0.40	5.94	13.26	138.8	13.9
Duttaphulia	7.02	0.14	6.11	19.15	285.3	43.6
Gayeshpur	4.85	0.05	6.40	10.35	168.9	28.1
Memari	7.71	0.34	7.50	14.83	137.7	41.1
Rangamati	6.20	0.43	6.80	12.50	326.9	54.7
Mandaron	7.82	0.22	4.90	12.30	312.5	32.8
Sonamukhi	7.15	0.28	9.49	17.20	109.7	50.2
Molebona	6.17	0.23	4.20	9.10	87.2	38.8
Piparjhori	5.49	0.69	2.74	8.22	148.3	38.4
Bishnupur	5.55	0.04	6.24	9.72	162.6	24.7
Joyrambati	6.42	0.06	4.22	16.54	223.3	37.5
Benechapra	5.84	0.04	9.42	10.84	149.9	29.3
Mondouri	7.33	0.43	5.70	12.80	122.4	15.6
Jaguli	5.38	0.11	5.50	7.80	295.8	52.2
Barabelu	5.61	0.46	7.60	14.60	154.8	39.6
Kamarpukur	5.80	0.10	4.10	9.10	292.4	38.2
Hoera	7.60	0.08	5.47	14.70	225.3	33.0
Dharmadanga	5.38	0.66	2.28	12.23	263.4	49.9
Sonamukhi	7.29	0.24	4.70	10.70	319.2	30.0
Manidaha	6.75	0.32	3.63	13.44	196.7	62.2
Beniasol	5.90	0.05	6.40	13.20	254.3	27.9
Nanduara	7.00	0.05	6.85	10.30	255.9	18.9
Chorchitta	6.04	0.21	4.11	11.64	236.6	65.7
Kajladaha	5.87	0.34	3.80	8.60	337.4	47.7
Sainthia	6.79	0.03	7.30	13.90	134.5	27.3
Kotasur	5.08	0.06	2.80	7.40	165.8	39.2
Bolpur	7.54	0.15	5.70	18.10	201.1	31.5
Bishpuria	4.52	0.22	2.13	11.65	74.1	18.2
Sindarpatti	6.09	0.07	9.27	15.91	280.2	31.5

TABLE 3. Different forms of K in the experimental field soils (mg kg^{-1})

Location of the soil	Water soluble K	Exchangeable K	Available K	Non-exchangeable K	Lattice K
Patchhara	13.0	86.2	99.2	544	2102
Shilkhuribos	9.2	50.3	59.5	342	1423
Daluadashgir	10.0	62.4	72.4	322	997
Bhogramguri	24.5	83.8	108.3	523	1990
Berhampore	27.0	137.1	164.1	416	1773
Golahat	32.1	256.1	288.2	654	2685
Gayeshpur	21.1	112.2	133.3	687	2695
Duttaphulia	5.8	98.5	104.3	2540	7820
Gayeshpur	16.0	118.1	134.1	1470	4760
Memari	34.4	158.1	192.5	917	2314
Rangamati	25.3	87.4	112.7	528	2067
Mandaron	6.7	80.5	87.2	610	3600
Range	5.8-34.4	50.3-256.1	59.5-288.2	322-2540	997-7820
Mean	18.8	110.9	129.7	796	2852
Sonamukhi	27.3	232.5	259.8	636	2125
Molebona	25.0	222.0	247.0	609	2089
Piparjhori	20.3	64.8	85.1	382	1229
Bishnupur	5.0	58.5	63.5	1290	3900
Joyrambati	10.3	119.0	129.3	1880	5230
Benechapra	9.5	78.0	87.5	830	2370
Mondouri	8.9	85.1	94.0	539	2459
Jaguli	14.5	127.0	141.5	1720	5130
Barabelu	38.2	324.5	362.7	1056	2879
Kamarpukur	14.0	112.4	126.4	1420	4800
Hoera	9.5	125.5	135.0	1220	4880
Dharmadanga	23.7	74.7	98.4	573	2290
Sonamukhi	18.6	69.9	88.5	486	1564
Manidaha	19.8	63.1	82.9	442	1353
Beniasol	11.0	71.4	82.4	1190	3560
Nanduara	6.2	60.5	66.7	1880	5930
Range	5.0-38.2	58.5-324.5	63.5-362.7	382-1880	1229-5930
Mean	16.4	118.1	134.4	1010	3237
Chorchitta	16.9	55.3	72.2	329	1081
Kajladaha	17.4	60.3	77.7	312	957
Sainthia	5.1	63.4	68.5	850	2620
Kotasur	14.2	85.5	99.7	1130	3530
Bolpur	16.5	111.3	127.8	1620	5180
Bishpuria	11.9	136.3	148.2	641	2320
Sindarpatti	13.5	141.5	155.0	890	2780
Range	5.1-17.4	55.3-141.5	68.5-155.0	312-1620	957-5180
Mean	13.6	93.4	107.0	825	2638

of 2985 mg kg^{-1} (Table 3). The corresponding values were 997-7820, 1229-5930 and 957-5180 mg kg^{-1} with a mean value of 2852, 3237 and 2638 mg kg^{-1} for Entisols, Inceptisols and Alfisols, respectively. The large variations in lattice K contents in soils might be due to the variations in the textural make up as well as the K-bearing minerals in finer fractions of the soils. The low values in some soils indicate that soil clay minerals likely to be highly depleted of reserve K due to intensive cropping with less K fertilizer application.

Relationship of K forms with soil properties and their interrelationship

In order to assess the influence of soil properties on various forms of soil K and their mutual associations, coefficients of correlation were worked out (Tables 4 and 5). Water soluble K had significant positive correlation with sand (r=0.340*) and EC (r=0.501**) and significant negative correlation clay (r=-0.309*). This implies that higher sand fraction and electrical conductivity and lesser clay content in soils reflects the higher concentration of water soluble K. Non-exchangeable K and lattice K showed strong significant negative correlation with sand (r=-0.695** and -0.704***, respectively) and significant positive correlation with clay (r=0.983*** and 0.960***, respectively). This indicates that finer fraction of the soils containing K-bearing minerals is the seat of reserve soil K. Regression analysis revealed that EC accounted for 25% of variability in water soluble K, while soil clay fraction could predict 97% and 92% of variability in non-exchangeable K and lattice K, respectively (Table not shown).

Water soluble K showed highly significant positive correlations with exchangeable K (r=0.674**) indicating rapid establishment of equilibrium between these forms, but significant negative correlations with non-exchangeable K (r=-0.339*) and lattice K (r=-0.391**) indicating difficulty in replenishment of available form of K from mineral K, once available pool of K is depleted (Singh *et al*., 1985). The strongly significant positive correlation between non-exchangeable K with lattice K (r=0.965***) suggests the good replenishment of non-exchangeable K upon depletion from mineral or lattice K.

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TABLE 4. Coefficients of correlation between forms of K and soil parameters

Soil parameter	Water soluble K	Exchangeable K	Available K	Non-exchangeable K	Lattice K
Sand	0.340*	-0.072	-0.022	-0.695**	-0.704***
Silt	-0.231	-0.009	-0.037	0.209	0.238
Clay	-0.309*	0.142	0.090	0.983***	0.960***
pH	-0.132	-0.108	-0.115	0.006	0.072
EC	0.501**	0.045	0.104	-0.584**	-0.567**
Organic C	-0.011	0.239	0.216	0.230	0.180
CEC	-0.056	0.116	0.098	0.258	0.250

*, **, *** indicate significant at 5, 1 and 0.1 % probability level, respectively

TABLE 5. Coefficients of correlation among different forms of soil K

Forms of K	Water soluble	Exchangeable	Available	Non-exchangeable
Exchangeable	0.674**			
Available	0.740***	0.995***		
Non-exchangeable	-0.339*	0.0745	0.0251	
Lattice	-0.391**	0.0560	0.002	0.965***

*, **, *** indicate significant at 5, 1 and 0.1 % probability level, respectively

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 141-148, 2016

Assessment of Variability and Genetic Divergence Study in Vegetable Cowpea [*Vignaunguiculata*(L.) Walp.] Genotypes

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Published : 30.10.2017

Abstract

Forty genotypes of cowpea [*Vignaunguiculata* (L.) Walp.] were investigated for yield and its component traits. High genetic variability was observed for green pod yield per plant, number of green pods per plant, number of branches per plant, plant height, pod length, ten pod weight, shelling % and crude protein along with high heritability and genetic advance, suggesting effective improvement of these characters through a simple selection programme. Mahalanobis'sD^2 analysis established the presence of wide genetic diversity among these genotypes by formation of eight clusters. Based on the mean performance and genetic divergence, the genotypes, GC 1, Kashi Kanchan, ACS 9, Swarna Sweta and Pusa Komal were identified as the suitable parents for crossing programme and further improvement in vegetable cowpea.

Key words *:* Vegetable cowpea, Variability, Heritability, Genetic gain, Genetic Divergence

Introduction

Cowpea [*Vignaunguiculata* (L.)Walp.] is one of the ancient crops known to man. It is cultivated around the world primarily for seed, but also used as a vegetable, cover crop and fodder. Its grain is rich in protein and digestible carbohydrate. Combined with cereals in the diet, lysine-rich cowpea complements the lysine-poor cereals. It is a fast growing, highly palatable and nutritious grain, fodder and vegetable crop. Hence, it is considered to be the most important leguminous crop. The crop is gaining popularity in developing and under developed countries, especially in arid region of the world due to its nutritional value and ability to withstand moisture stress condition. Information on the genetic variability is an important prerequisite for better response to selection. The breeder should be able to distinguish the genetic and non-genetic component of variability.

The choice of genetically diverse parents for hybridization is important which may lead to a broad spectrum of favorable genetic variability for yield improvement. The D^2 analysis proposed by Mahalanobis (1936) is an effective tool in qualifying the degree of genetic divergence among the parents. In the present investigation, variability and diversity were estimated in vegetable cowpea.

Materials and Methods

The present study comprises 40 genotypes of vegetable cowpea of different region evaluated at Main Vegetable Research Station, AAU, Anand during *Summer*-2013. The genotypes were laid in randomized block design with three replications at 45 and 30 centimeters inter row and intra row spacing, respectively. Each entry was represented by two rows of three meters length per replication. Observation were recorded on ten randomly selected plants per replication for seventeen important quantitative traits namely, green pod yield per plant, number of green pods per plant, days to 50% flowering, days to first picking, number

of branches per plant, plant height, pod length, pod girth, ten pod weight, shelling %, number of pods per cluster, number of seeds per pod, 100 seed weight, chlorophyll content, moisture %, ash content and crude protein content. The chlorophyll content was estimated as per the method suggested by Hiscox and Israelstam (1979), and moisture %, ash content and crude protein content were worked out as per AOAC(1965). The data obtained from these different characters was subjected to different procedure for computation of genotypic and phenotypic coefficient of variance (GCV and PCV), heritability in broad sense (h^2) and genetic advance as per cent of mean (GA). The genetic divergence among the genotypes was calculated using the method developed by Mahalanobis (1936).

Results and Discussion

The analysis of variance revealed highly significant differences among genotypes for all the characters under investigation designating the presence of considerable amount of variability in the material (Table 1). Variability parameters worked out for the seventeen traits are presented in (Table 2).In the present study, green pod yield per plant, number of pods per plant, number of branches per plant, plant height, pod length, pod girth, 10 pod weight, shelling %, chlorophyll content and crude protein showed high GCV estimates. High estimates of genotypic coefficient of variation for green pod yield per plant, number of pods per plant, number of branches per plant, plant height, pod girth and ten pod weight were also observed by Mishra and Dash (2009) and Prasanthi (2004) recorded for pod length. Hence, selection for these characters having high genetic variability would facilitate successful isolation of desirable types for these characters.

In the present investigation, all the traits except days to 50 % flowering, days to first picking, number of pods per cluster and number of seeds per pod were found to exhibit high heritability coupled with high genetic advance, indicating the preponderance of additive gene action in inheritance of green pod yield per plant, number of green pods per plant, number of branches per plant, plant height, pod length, pod girth, ten pod weight, shelling %, 100 seed weight, chlorophyll content, moisture %, ash content and crude protein. That means these characters would respond effectively to phenotypic selection. These results are in conformity with that of Mishra and Dash (2009).

The success of hybridization programme depends on the genetic diversity present in the parents. Morphological diversity analysis of all the sixteen characters under study was made on the basis of mean values using Mahalanobis D^2 statistics. In this study 40 genotypes vegetable cowpea grouped into eight clusters. Among the eight clusters the cluster I was the largest followed by the cluster II while the cluster VIII was smallest with single genotype (Table 3). Similar irregular clustering pattern of genotype distribution has been reported by Dalsaniya *et al.* (2009). The clustering pattern of the varieties in the present investigation clearly indicated that there was no parallelism between genetic and geographic diversities. It may be due to free exchange of genetic material from one place to another or due to the fact that unidirectional selection practiced in different place might have had a similar effect and therefore, varieties evolved under similar selection pressure might have clustered together irrespective of their geographic origin.

The inter-cluster distances were higher than the average intra-cluster distances, which indicated wide genetic diversity among the cowpea accessions of different groups than those of same cluster (Fig. 1). The maximum inter-cluster distance was exhibited by cluster II and VII (D^2=26.63) followed by cluster VI and VIII (D^2= 26.14) and cluster II and III (D^2= 24.46). Therefore, genotypes from above cluster may be selected for hybridization for increasing chances for getting better segregates and desirable recombinants. The maximum intra-cluster distance was observed in cluster I (D^2= 43.16) followed by cluster VII (D^2= 20.12) and cluster VI (D^2= 17.52) indicating higher genetic variability among genotypes within clusters.

Based on the cluster means for different traits (Table 4) cluster III is important for minimum days to 50% flowering and days to first picking. Cluster VIII for green pod yield per plant, number of pods per cluster and number of seeds per pod. Cluster III for number

TABLE 1. Analysis of variance (mean sum of squares) for different characters in cowpea.

Sr. No.	Character	Source of Variance		
		Replication	Genotype	Error
	Degree of freedom	2	39	78
1	Green pod yield per plant	225.190	2168.877**	126.362
2	Number of green pods per plant	9.736	82.105**	4.452
3	Days to 50 % flowering	7.008	46.468**	4.222
4	Days to first picking	1.608	28.453**	4.437
5	Number of branches per plant	0.057	12.902**	0.440
6	Plant height	56.093	9665.522**	162.498
7	Pod length	9.021	41.614**	3.469
8	Pod girth	0.024	0.580**	0.067
9	Pod weight	33.581	1249.751**	49.886
10	Shelling %	4.000	463.406**	21.156
11	Number of pods per cluster	0.022	0.714**	0.242
12	Number of seeds per pod	0.331	4.817**	1.136
13	100 seed weight	2.581	26.001**	2.363
14	Chlorophyll content	0.001	0.342**	0.011
15	Moisture percentage	7.156	205.662**	6.108
16	Ash content	0.164	2.139**	0.066
17	Crude protein (%)	3.544	15.683**	1.187

of pods per plant and shelling %. Cluster IV for number of branches per plant. The maximum mean value for plant height recorded by cluster V and cluster II confirmed the maximum pod length and ten pod weight. Cluster VII authenticated the maximum mean value for pod girth, ash content and crude protein content. Likewise, cluster VI showed the highest mean value for 100 seed weight, chlorophyll content and moisture %. Likewise, different yield attributing characters recorded highest cluster mean values in different clusters was found by in Nagalakshami *et al.* (2010) cowpea.

The genotypes from cluster III and cluster VIII with high cluster mean for yield as well as yield contributing characters and low cluster mean for days to 50% flowering and days to first picking may be selected for hybridization in achieving improvement in yield and early maturity in vegetable cowpea. Genotypes among the cluster separated by high D^2 values could be used in hybridization program for obtaining wide spectrum of variations among the segregates. It is desirable to perform cross between genotypes belonging to the distant clusters for high heterotic response.

The percentage contribution of different important traits towards the genetic divergence (Table 5) indicated that moisture % contributed maximum to the total divergence followed by plant height and

Table 2. The estimates of genotypic and phenotypic variances and other genetic parameters for different characters in cowpea.

Sr.No	Character	$\sigma^2 g$	$\sigma^2 p$	GCV (%)	PCV (%)	H^{2b} (%)	GA (%)
1	Green pod yield per plant	649.36	798.94	30.40	33.72	81.3	56.46
2	Number of green pods per plant	25.88	30.33	25.76	27.89	85.3	49.03
3	Days to 50 % flowering	14.06	18.29	10.04	11.45	76.9	18.15
4	Days to first picking	8.00	12.43	5.44	6.78	64.3	9.00
5	Number of branches per plant	4.15	4.59	34.68	36.47	90.4	67.97
6	Plant height	3167.88	3330.84	43.31	44.41	95.1	87.01
7	Pod length	12.71	16.18	20.72	23.37	78.6	37.82
8	Pod girth	0.17	0.23	19.60	23.10	72.0	34.12
9	Ten pod weight	400.00	449.81	40.71	43.78	88.9	79.09
10	Shelling %	146.41	170.63	26.66	28.78	85.8	50.88
11	Number of pods per cluster	0.15	0.39	11.23	17.88	39.4	14.44
12	Number of seeds per pod	1.22	2.36	8.87	12.30	51.9	13.13
13	100 seed weight	7.88	10.23	16.61	18.93	77.0	30.05
14	Chlorophyll content	0.11	0.12	19.18	20.07	91.3	37.57
15	Moisture %	66.46	72.67	10.54	11.02	91.6	20.78
16	Ash content	0.69	0.75	16.43	17.20	91.2	32.47
17	Crude protein	4.83	6.01	22.28	24.87	80.3	41.17

number of branches per plant. There is always difference in opinion in specifying the trait that is contributing high or low towards the genetic diversity. The contribution mainly depends upon the genotypes included in the study and the environment influenced over the character. Regarding the least contribution, number of pods per cluster and number of seeds per pod contributed the least. The minimum contribution by this trait reveals that trait was least affected in course of evolution. However, Indradeo (2007) was observed maximum contribution of characters to divergence for pod length, plant height and number of branches per plant.

By considering all the diversity and mean performances it can be concluded that genotypes GC 1, Kashi Kanchan, ACS 9, Swarna Sweta were found to be best for crossing and yield improvement in cowpea. Pusa Komal was recorded best for improving protein quality in vegetable cowpea. While, for reducing maturing duration ACS 9 and Swarna Suphala can be considered.

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TABLE 3. Distribution of 40 genotypes of cowpea to different clusters on the basis of D^2-statistics.

Sr. No.	Clusters	No. of genotypes	Name of the genotypes	Source
1	I	24	GP 9, GP 24, GP 25, GP 31, GP 47, GP 16, CPD 77, CPD 103, CPD 78, CYACP 35, GP 63, AVCP 1	AAU., Anand
			JCPL 8, JCPL 99, JCPL 2000-4, JCPL 2001-1	JAU, Junaghadh
			Swarna Harita	RCER, Patna
			Arka Gomati	IIHR, Bangalore
			Kashi Gauri, Kashi Annanti	IIVR, Varansi
			GC 2, GC 4	SDAU, Dantiwada
			Pusa Sukomal, Pusa Phalguni	IARI, New Delhi
2	II	3	JCPL 7	JAU, Junaghadh
			Swarna Sweta	RCER, Patna
			Kashi Kanchan	IIVR, Varansi
3	III	4	GP 62, ACS 9, RC 101	AAU., Anand
			Kashi Sudha	IIVR, Varansi
4	IV	2	JCPL 2001-2	JAU, Junaghadh
			ACS 2001-1	AAU., Anand
5	V	2	GP 64	AAU., Anand
			Swarna Suphala	RCER, Patna
6	VI	2	Arka Garima	IIHR, Bangalore
			GC 3	SDAU, Dantiwada
7	VII	2	JCPL 2000-2	JAU, Junaghadh
			Pusa Komal	IARI, New Delhi
8	VIII	1	GC 1	SDAU, Dantiwada

TABLE 4. Clusters mean value of different seventeen characters in vegetable cowpea.

	I	II	III	IV	V	VI	VII	VIII	Contribution (%)
Green pod yield/plant (g)	78.65	**129.29**	73.97	82.07	82.90	90.76	68.63	132.64	1.02
Number of green pods/plant	19.54	13.61	23.88	19.62	20.13	22.83	19.81	19.74	2.56
Days to 50 % flowering	38.56	36.55	32.75	36.50	36.83	35.66	35.50	39.00	1.79
Days to first picking	53.05	50.33	48.91	51.00	48.66	51.83	51.83	53.66	0.38
Number of branches/ plant	5.40	4.25	6.94	10.91	8.68	5.35	5.66	3.55	11.79
Plant height (cm)	**122.98**	126.57	**79.89**	**90.62**	**252.44**	**184.96**	**184.41**	**122.35**	19.74
Pod length (cm)	16.56	*27.00*	14.32	18.36	18.80	15.88	14.44	17.78	*0.00*
Pod girth (cm)	2.05	2.21	2.42	2.19	*1.99*	*1.80*	2.44	1.96	1.28
Ten pod weight (g)	45.41	111.53	34.36	47.57	46.42	39.87	42.15	50.95	8.07
Shelling %	47.20	27.95	57.20	47.27	45.93	18.79	49.43	46.97	1.79
Number of pods/cluster	3.53	3.15	3.35	3.42	3.81	3.50	3.82	4.53	0.12
Number of seeds/pod	12.37	13.53	11.70	13.16	13.53	12.92	11.11	13.86	0.25
100 seed weight (g)	16.52	19.54	16.62	17.06	15.24	21.84	14.56	16.91	5.12
Chlorophyll (mg)	*1.60*	*1.80*	*2.11*	*1.34*	2.14	2.35	*1.97*	*1.40*	9.48
Moisture %	76.92	82.27	70.69	82.51	86.74	87.24	74.74	56.04	**26.41**
Ash content (g)	4.75	5.34	4.87	4.72	5.26	5.98	7.77	5.33	8.46
Crude protein (%)	9.69	7.84	11.63	9.88	7.91	9.49	14.07	9.09	1.66

Maximum and minimum values of each character are printed in bold and italics, respectively

TABLE 5. Relative contribution of seventeen characters towards genetic divergence in 40 vegetable cowpea germplasm.

Sr No.	Characters	Number of times ranked first	Contribution(%)
1	Green pod yield per plant (g)	8	1.02
2	Number of green pods plant	20	2.56
3	Days to 50 % flowering	14	1.79
4	Days to first picking	3	0.38
5	Number of branches per plant	92	11.79
6	Plant height (cm)	154	19.74
7	Pod length (cm)	0	0.00
8	Pod girth (cm)	10	1.28
9	Ten pod weight (g)	63	8.07
10	Shelling %	14	1.79
11	Number of pods per cluster	1	0.12
12	Number of seeds per pod	2	0.25
13	100 seed weight (g)	40	5.12
14	Chlorophyll (mg)	74	9.48
15	Moisture %	206	26.41
16	Ash content (g)	66	8.46
17	Crude protein (%)	13	1.66
	Total	780	100

Figure 1. Clustering pattern of different group with inter cluster and intra cluster distance among the cowpea genotypes.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 149-152, 2016

Evaluation of Soil Nitrogen Status in Some Tropical Soils of India

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Published : 30.10.2017

Abstract

This study determines the changes of different fractions N from forest to agricultural land. Changes in soil N are assess by laboratory analysis and estimation. Agricultural land possesses higher nitrate (NO_3^-) concentration, whereas ammonium concentrations are high in forest soils and attain a steady state with respect to time. Total N and plant available forms are higher in forest land in comparison with agricultural soil, this is due to higher organic carbon, soil reaction and amount of Iron and aluminium content. In forest land ammonification and nitrification are nearly equivalent, whereas nitrification process exceeds the ammonification in arable agricultural land.

Keywords : agricultural land, forest soils, N-fractions

Introduction

Nitrogen is an integral component of many essential plant compounds. It is a major part of all amino acids which are the building blocks of all proteins including the enzymes which controls virtually all biological processes. Soil nitrogen plays an important role in the cycle of environmental system not only as a sink but also as a source. The total N content has been reported by several authors (Tan 1968; Kawaguchi and Koyama 1977). However, a comprehensive evaluation of soil Nitrogen fractions has not been carried out in spite of its potential importance for the establishment for the rational soil management for the sustainable and productive agriculture. Matavalli and Mc Connell (1998) showed that in Guam Island, the contents of total N, active N and stabilized N of soils at forested sites were higher than those of soils under sites of continuous cultivation. Soil types affected the soil N mineralization rate (Gonzaler- Prieto et al., 1996). Soil nitrogen has been fractioned into labile and stable fractions (Motovalli and Mc Connell, 1998). Soil nitrogen is also fractioned into inorganic labile-N, inorganic stable-N, and organic labile-N (Yanai et al., 2011). The objective of this study was to examine the N status from agricultural to forest land.

Materials and Methods

Soil sampling

Soil samples were collected from two different agricultural fields and two forest area of West Bengal, India. Sampling site, soil classification and vegetation types are listed in Table 1. Soil samples were collected in may-June 2016 from agricultural (A_p) and forest land (A_h). Soils were sieved (2mm) to remove larger roots and animals are stored in field moist at 25^o C in polythene bags for upto 3 weeks. Before use, soil samples were equilibrated at room temperature for 3-4 days. Sample then passed through 2 mm sieve, then used for analysis purpose. Soil analysis data are listed in Table 2.

Physico-chemical analysis

Soil pH as measured in a 1:1 soil : solution in H_2O and 1M KCl (National Soil Survey Centre, 1996), Organic Carbon (OC) was measured by the Walkley-Black method (Nelson and Sommers,1996) and used to calculate the amount on Organic matter (OM) (OM= OCX1.742). Nitrogen was measured by a analyzer (dry combustion) (Elliott et al., 1991). Cation exchange capacity was determined by NH_4OAC at pH 7.0 and is defined by the some of the exchangeable cations that

Table 1. Sampling site, soil order, vegetation type and texture

Sl. No.	Location	Soil order	Vegetation type	Texture
1.	Baruipur soil, West Bengal, $22^0$35´N, 88^0 44´E	Entisol	Rice-rice-rice	46%silt, 19%clay, 35%sand
2.	Amtala soil, West Bengal, India, 21.99^{0}N, 87.88^{0}E	Fluvaquent	Rice-rice-rice	34%silt, 26%clay, 40%sand
3.	Gopghar soil, West Bengal, India22.58^{0}N, 87.04^{0}E	Haplustalfs	Tropical forest	26%silt, 36%clay, 38%sand
4.	Lalgola Soil West Bengal, India 23.59^{0}N, 88.39^{0}E	Haplustepts	Tropical forest	25 % silt, 45 % clay, 30 % sand

Table 2. Chemical and physical characteristics of soils

Soil Sample	pH $_{water}$	EC mSm^{-1}	%O.C	%O.M	Av. N (g/Kg)	Tot. N (g/Kg)	Av. P (g/Kg)	Av. Fe (g/Kg)	Ex.Ca (g/Kg)	Ex.Mg (g/Kg)
Baruipur Soil	6.10	0.06	1.257	2.17	0.171	1.01	0.023	0.23	2.9	0.8
Amtala Soil	7.2	0.08	1.45	2.51	0.282	1.25	0.04	97.9	2.8	0.6
Gopghar Soil	5.25	0.07	1.85	3.22	0.490	1.82	0.32	83.6	4.5	1.2
Lalgola Soil	5.2	0.02	1.98	3.42	0.527	2.11	0.41	265.2	5.2	1.8

*EC=electrical conductivity, Av= Available, OC= organic carbon, OM= organic matter, Ex= Exchangble

a soil can absorb (Chapman, 1965). Particle size distribution was analysed by the pipette method (Gee and Bauder., 1986). Specific surface area was analyzed by N2-BET method (Aylmore *et al.*, 1970).

Total nitrogen, available nitrogen, ammonium nitrogen, nitrate nitrogen, nitrite nitrogen were measured using Kelplus Nitrogen Analyser.

Results and Discussion

Soil and clay properties are summarized in Table 2, where it can be seen that forest soils were acidic in pH (pH 5.2-5.25) and clay content are high, and rich in organic carbon (1.85%-1.95%). On the other hand agricultural soils are nearly neutral or neutral in nature (pH 6.1-7.2) and poor in organic carbon status (1.25%-1.45%). Amount of total N and Fe status are high in forest soil in comparison with agricultural soil. Estimated different fractions of nitrogen are listed in Table 3. Ammonium concentration in Baruipur, Amtala, Gopghar and Lalgola soil are 0.039, 0.032, 0.098 and 0.089g/kg respectively whereas nitrate concentration in those above mentioned soil are 0.022, 0.025, 0.076

TABLE 3. Different fractions of nitrogen.

Soil	NH_4^+	NO_3^-	NO_2^-	Total- N
Sample	g/kg	g/kg	g/kg	g/kg
Baruipur Soil	0.039	0.022	0.0098	0.344
Amtala Soil	0.032	0.025	0.0099	0.421
Gopghar Soil	0.098	0.076	0.0141	0.872
Lalgola Soil	0.089	0.052	0.0132	0.911

and 0.052g/kg respectively. Total N status in these soils is 0.344, 0.421, 0.872 and 0.911g/kg respectively.

Available phosphorous status also high in forest land compare to agricultural soil even calcium, magnesium status are also rich in forest sites. From N fractionation analysis it was observed that ammonium, nitrate and nitrite fraction are poor in agricultural soil compare to forest soil. Ammonium (NH_4^+) and nitrate (NO_3^-) concentration estimated in different time intervals. From figure 1&2 it was observed that ammonification and nitrification are nearly equivalent in forest land and attain a steady value with respect to time whereas in agricultural soil conversion of ammonium to nitrate is too faster and reaction rate for that conversion are much high than the conversion of nitrate to ammonium, this is due to arable farming and nearly neutral pH range that stimulate nitrification process of agricultural soil.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 153-158, 2016

Bio-Efficacy of Some Molecules against Whitefly, *Bemisia Tabaci* (Gennadius) on Chilli

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Published : 30.10.2017

Abstract

Field experiment was conducted at 'D' block farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Benagal ($22^0$58'52" N; $88^0$26'30" E, 10 m above sea level), India during *rabi* season for consecutive two years 2014-15 and 2015-16 to determine the comparative efficacy of some molecules against one of the major sucking pest, whitefly, *Bemisia tabaci* Gennadius in chilli. Two applications of diafenthiuron 40.5% + acetamiprid 3.9% WP at three different doses viz. 400 g, 500 g and 600 g per ha each along with diafenthiuron 50 WP @ 600 g/ha, acetamiprid 20 SP @ 100 g/ha, fenpropathrin 30EC @ 340ml/ha and untreated control were made at 15 days interval during this trial. Among the different treatments diafenthiuron 40.5% + acetamiprid 3.9% WP @ 600 g/ha was the most effective for controlling this sucking pest in both the years, though it is statistically at par with the same product when applied at 500 g/ha. Second best result was obtained from T_5 i.e. acetamiprid 20 SP @ 100 g/ha. The maximum yield (4.82 t/ha) was recorded in T_3 i.e. diafenthiuron 40.5% + acetamiprid 3.9% WP @ 600 g/ha followed by its next lower dose i.e diafenthiuron 40.5% + acetamiprid 3.9% WP @ 500 g/ha (4.69 t/ha).

Key words : Bio-efficacy, Diafenthiuron + Acetamiprid, whitefly, management, chilli.

Introduction

Chilli (*Capsicum annum* L.) is an important spice crop, commonly used in Indian dietary and grown throughout the year. In West Bengal, the chief chilli growing districts are South and North 24 Parganas, Howrah, Hooghly, Nadia, Murshridabad, Malda, Jalpaiguri and Cooch Behar. It is considered as one of the major remunerative cash crops to the farmers of West Bengal. This highly remunerative and useful crop is known to be attacked by over 20 insect and non-insect pests in India (Butani, 1976). The whitefly, *Bemicia tabaci* (Gennadius) is one of the most damaging pest attacking a wide range of important crops including vegetables and ornamentals all over the world (Perring, 2001; Carabali *et al*., 2005; Touhidul and Shunxiang, 2007; Abdel-Baky and Al-Deghairi, 2008) due to not only its direct damage by sucking plant sap but also its ability to transmit various viral diseases (Oliveira *et al*., 2001; Al-Deghairi, 2009). However, management of *B. tabaci* is challenging because of its intercrop movement, high reproductive potential and it's at under leaf habitat (Gerling *et al*., 2001; Al-Deghairi, 2009; Fouly *et al*., 2011). Minimizing the

whitefly damage in crop production by using chemical insecticides has been the most effective method during the last decades, although such practice is hazardous to our environment. On the other hand, the indiscriminate use of these chemical pesticide leads to incidence of resistance to many conventional insecticides which has lead to the development of large numbers of new active compounds such as the neo-nicotinoids (Wafaa A. Al-Kherb, 2011), diafenthiuron.

Therefore, the present study was conducted to evaluate a combined product of diafenthiuron and acetamiprid at three different doses against whitefly on chilli under field conditions.

Materials and Methods

The present experiment was conducted at 'D' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal ($22^0$58'52" N; $88^0$26'30"E, 10 m above sea level) for consecutive two years during 2014-15 and 2015-16 crop seasons. In order to evaluate the bio-efficacy of a combined product Diafenthiuron 40.5% + Acetamiprid 3.9% WP against whitefly, field was laid out with 21 plots each of measuring 5 x 5 sq. m . Row to row and plant to plant distance of 30 cm and 30 cm respectively were maintained. Altogether, there were seven treatments viz.T_1= Diafenthiuron 40.5% + Acetamiprid 3.9% WP@ 400 g/ha, T_2 = Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 500 g/ha, T_3 = Diafenthiuron 40.5% + Acetamiprid 3.9% WP@ 600 g/ha, T_4= Diafenthiuron @ 600 g/ha, T_5 = Acetamiprid 20 SP @ 100g/ha, T_6= Fenpropathrin 30EC @ 340ml/ha, and T_7= Untreated control. Each of the treatments was replicated thrice. Spraying was done during the crop season by using 500 litres of spray solution per hectare with high volume knapsack sprayer. The first round spray was initiated after the pest population crossed the ETL and subsequent sprays were done at 15 days interval. Two rounds of spray were done in both the year. The data of target pests were recorded from randomly selected five plants in each plot. In case of white fly, number of nymphal population was recorded from lower surface of top five leaves per plant from five randomly selected plants of each replication per treatment and total number was counted accordingly. First count was taken one day before first spray and post treatment counts were recorded on 5, 10 and 15 days after spray. The green chilli yield (t/ha) from each plot was recorded and analyzed statistically. The data were subject to analysis after making necessary transformation and expressed on the basis of percent reduction of pest population.

Results and Discussion

Three doses of Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 400, 500, and 600 g/ha along with the single dose of Diafenthiuron 50 % WP @ 600 g/ha, Acetamiprid 20 SP @100 g/ha and Fenpropathrin 30 EC @340 ml/ha were sprayed to work out their efficacy against whitefly. The data on the result of experiment for both the years has been presented in the table 1 and table 2.

The pre count population of whitefly, *B. tabaci* showed the homogeneous distribution in all the treatments (Table-1). Five days after first round spray, maximum mortality of whitefly was recorded from Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 600 g/ha (T_3) which was statistically at par with Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 500 g/ha (T_2) where 79.87 and 79.27 percent mortality was recorded respectively. The lowest mortality percent was observed in the plots treated with Fenpropathrin 30 EC @ 340 ml/ha (69.09%). The similar trend of result was also been recorded at 10 DAS, 15 DAS and after second round of spray.

In the second year of study (Table-2) the maximum per cent of mortality (78.20%) of whitefly was registered from Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 600 g/ha which was statistically at par with Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 500 g /ha (74.68%) at 5 DAS. Acetamiprid 20 SP @ 100 g/ha was recorded the next best treatment (71.61%) which was statistically at par with Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 400 g/ha and diafenthiuron 50 WP @ 600 g/ha (71.21% and 70.09% respectively) at 5 days after spray. Lowest per cent of mortality (60.93%) recorded from Fenpropathrin 30 EC @ 340 ml/ha after 5 days of

Table 1. Impact of combine product Diafenthiuron 40.5% + Acetamiprid 3.9% WP against whitefly in chilli during the experimental period of 2014-15 (1st year)

Treatment	Dosage g or ml/ha	Pre treated pop./plant	% mortality of whitefly after 1st round spray				% mortality of whitefly after 2nd round spray			
			5 DAS	10 DAS	15 DAS	Mean	5 DAS	10 DAS	15 DAS	mean
T_1= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	400	13.96	74.86 (60.24)*	67.22 (55.38)	50.20 (45.40)	64.09	71.50 (58.05)	62.26 (52.39)	48.76 (44.58)	60.84
T_2= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	500	14.29	79.27 (63.27)	73.82 (59.55)	59.74 (50.91)	70.94	78.84 (62.97)	72.24 (58.53)	58.60 (50.24)	69.89
T_3= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	600	14.62	79.87 (63.70)	75.05 (60.37)	61.92 (52.19)	72.28	79.46 (63.41)	73.95 (59.63)	59.95 (51.03)	71.12
T_4= Diafenthurion 50WP	600	14.22	72.18 (58.49)	63.15 (52.92)	52.30 (46.60)	65.54	72.78 (58.87)	60.00 (51.06)	47.70 (43.97)	60.16
T_5= Acetamiprid 20SP	100	14.33	70.33 (57.31)	61.44 (51.91)	51.85 (46.35)	61.20	71.60 (58.12)	58.07 (49.94)	47.52 (43.86)	59.06
T_6= Fenpropathrin 30EC	340	14.82	69.09 (56.54)	59.96 (51.04)	43.62 (41.63)	57.55	67.76 (55.71)	56.49 (49.02)	39.99 (39.52)	54.74
T_7= Untreated control	—-	13.78	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	—	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	—
S. Em. ±		—	1.53	0.76	2.04		0.62	0.84	1.31	—
CD (0.05)		—	4.73	2.33	6.28		1.90	2.57	4.04	—
CV (%)		—	0.67	0.39	1.22		0.27	0.44	0.81	—

* Values in the parentheses are angular transformed, DAS: Days after spraying, pop.- population

Table 2. Impact of combine product Diafenthiuron 40.5% + Acetamiprid 3.9% WP against whitefly in chilli during the experimental period of 2015-16 (2nd year)

Treatment	Dosage g or ml/ha	Pre treated population /plant	% mortality of whitefly after 1st round spray				% mortality of whitefly after 2nd round spray			
			5 DAS	10 DAS	15 DAS	Mean	5 DAS	10 DAS	15 DAS	mean
T_1 = Diafenthiuron 40.5% + Acetamiprid 3.9% WP	400	7.33	71.21 (57.87)*	60.72 (51.49)	51.00 (45.86)	60.97	71.31 (57.93)	61.85 (52.15)	45.85 (42.91)	59.67
T_2= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	500	7.20	74.68 (60.12)	66.93 (55.20)	57.19 (49.42)	66.26	75.55 (60.70)	70.47 (57.40)	57.97 (49.87)	67.99
T_3= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	600	7.00	78.20 (62.52)	69.85 (57.01)	59.08 (50.52)	69.04	76.98 (61.67)	72.20 (58.50)	61.59 (51.99)	70.25
T_4= Diafenthurion 50 WP	600	7.33	70.09 (57.16)	62.99 (52.83)	50.43 (45.53)	61.17	70.32 (57.30)	62.51 (52.54)	48.29 (44.31)	60.37
T_5=Acetamiprid 20 SP	100	8.20	71.61 (58.12)	63.70 (53.25)	53.75 (47.44)	63.02	72.02 (58.38)	64.50 (53.73)	51.57 (46.19)	62.69
T_6= Fenpropathrin 30 EC	340	6.93	60.93 (51.61)	50.66 (45.67)	39.99 (39.52)	50.52	60.47 (51.34)	50.76 (45.72)	32.57 (35.11)	47.93
T_7= Untreated control	—-	6.80	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	-	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	-
S. Em. ±	—-	NS	1.40	1.78	2.29	-	1.51	2.02	2.28	-
CD (0.05)	—-	—	4.30	5.50	7.05	-	4.64	6.23	7.02	-
CV (%)	—-	—	0.64	0.96	0.41	-	0.70	1.07	1.43	-

* Values in the parentheses are angular transformed, DAS: Days after spraying, pop. - population

TABLE 3. Cumulative yield of green chilli in t/ha

Treatments	Dosage (g or ml /ha)	Yield of green chilli in 1st year (t/ha)	Yield of green chilli in 2nd year (t/ha)	Mean
T_1= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	400	4.18	3.98	4.08
T_2= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	500	4.83	4.55	4.69
T_3= Diafenthiuron 40.5% + Acetamiprid 3.9% WP	600	4.85	4.80	4.82
T_4= Diafenthurion 50 WP	600	4.12	4.00	4.06
T_5=Acetamiprid 20 SP	100	3.67	3.90	3.78
T_6= Fenpropathrin 30EC	340	3.28	3.38	3.33
T_7= Untreated control	—	2.90	2.93	2.91
S. Em. ±		0.12	0.15	-
CD (0.05)		0.35	0.48	
CV(%)		0.66	0.99	

spraying. The similar trend of result was also been recorded after second round of spray. The present result were in harmony with Ali *et al.* who reported that acetamiprid 20 SP was more effective when compared to diafenthiuron 500 EC and imidacloprid 300 SL against nymphal population of whiteflies in cotton. Khattak *et al*. also reported that acetamiprid 20 SP, diafenthiuron 50 WP and thiamethoxam 25 WG were more effective than imidacloprid 200 SL against whitefly in moong bean.

The data on green chilli yield revealed that all the treatments were significantly superior over untreated control (Table-3). Highest green chilli yield was harvested from Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 600 g/ha (4.82 t/ha), which was statistically at par with Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 500 g/ha (4.69 t/ha). The next best yield was obtained from Diafenthiuron 40.5% + Acetamiprid 3.9% WP @ 400 g/ha (4.08 t/ha) followed by Diafenthiuron @ 600g/ha (4.06 t/ha). The treatment Acetamiprip 20 SP (3.78 t/ha), Fenpropathrin (3.33 t/ha) along with untreated control (2.91 ton/ha) were recorded relatively low yield.

From the present study it may be concluded that diafenthiuron 40.5% + acetamiprid 3.9% WP @ 600 g/ha was the most effective pesticide for controlling the whitefly in chilli.

Acknowledgement

Authors are thankful to Vice-Chancellor, Bidhan Chandra Krishi Viswavidyalaya, West Bengal and Insecticide India Ltd. for providing fund and facilities for preparation of this manuscript. We also transmit our warm gratitude to the Department of Agril. Entomology, BCKV.as well as all those who have contributed their kind helps and supports.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 159-166, 2016

Depthwise and Spatial Variation of Arsenic in a Tropical Mangrove Dominated Matla Estuary

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Published : 30.10.2017

Abstract

This study represents arsenic distribution in the Sundarban mangrove dominated Matla estuary and the importance of this ecosystem as the source of arsenic for surrounding estuarine water. Arsenic concentration in tidal water, pore water and ground water demonstrated strong seasonal variations. Concentration of arsenic found to be increased with increase in depth which suggested that arsenic supply seems to have declined.

Keywords : Arsenic, Seasonal variation, Mangrove

Introduction

Arsenic is found to occur in the Marine and esturine environment and can be toxic to marine organisms at high concentration (Cutter and Cutter, 1995). Arsenite [As (III)] and arsenate [As (V)] species are the most common forms in natural system. Inorganic forms are typically more abundant than organic form in the aquatic system. Mobility and toxicity strongly depend on the oxidation state of inorganic form and As (III) is very toxic than As (V) and organic species of As (Ng *et al*., 2003). Inorganic arsenic is a human carcinogen, the World health organization (WHO) set a standard at no more than 10 $\mu g.L^{-1}$ of arsenic in drinking water and however 50$\mu g.L^{-1}$ is the maximum contamination level (MCL) considered acceptable in India. Inhibited concentration of arsenic in ground water across Southern Asia slowly poison over 100 millions villagers relying on in expensive shallow tube wells. The level of exposure has caused wide spread illness including deadly cancers and significantly hampers the mental development of children. The toxicity of As (V) is due to its interference with oxidative phosphorylation in cells, by substituting for phosphorous in adenosine triphosphate (ATP) synthesis, essentially deactivating intracellular energy storage. As (III) toxicity is caused by a strong affinity for Sulfhydryl groups, such as thiol groups in enzymes (NRC, 1999; 2001). Organic arsenic is less toxic than the inorganic species, and methylation of inorganic arsenic is one type of detoxification mechanism for some bacteria, fungi, phytoplankton, and higher level organism such as humans. Methylation can also occur when organisms are stressed from nutrient limitation (Anderson and Bruland, 1991, Ng *et al*., 2003). To mitigate arsenic contamination especially, the elevated concentration of arsenic in ground water, it is important to understand the specific biogeochemical controls of arsenic mobility in sediment- water system. In its natural state arsenic is usually associated with sulphide ores. Over 100 minerals and ores contain arsenic. The principal arsenic-bearing minerals include: arsenopyrite (FeAsS), niccolite (NiAsS), Cobaltite (CoAsS), tennantite ($Cu_{12}As_4S_{13}$), enargite (Cu_3AsS_4). The principal arsenic compounds produced are arsenic trioxide (As_2O_3) and arsenic elements from which other compounds are made (Ehelich, 1995). Arsenic is the 20-th most abundant element (2 – 3 mg Kg^{-1}) in the earth's crust and ground water contamination by arsenic is often due to naturally occurring arsenic deposit. Arsenic is one of the components of a large number of compounds generated by human activities

(precious metals mining, manufacturing, wood preservatives, glassmaking industry, electronics industry, chemical weapons etc.) (Han *et al*., 2003 & Kohler *et al*., 2001). Phytoplankton plays an important role in the conversion of arsenic from dissolved to particulate form. Partitioning of arsenic in the particulate and dissolved form and sedimentation from water column to the sediment could be enhanced by the production of autochthonous organic matter (Faye and Diamond, 1996). Arsenic reduction for many bacteria is considered to be a detoxification mechanism since it enhances removal of As (III) from the cell (Dowdle *et al*., 1996), although not always. Cell-free extract of *Micrococcus lactilyticus*, containing an active enzyme hydrogenase, reduced As (V) to As (III) but As (III) was not further reduced (Wool folk & Whiteley, 1962). Arsenic can be oxidized by several microorganisms including bacteria, fungi and algae. Bacterial oxidation of As (III) to the less toxic As (V) was first observed by Green in 1918 (cited in Ehrlich 1995), who isolated *Bacillus arsenoxydans* from arsenical cattle-dipping solution. Arsenic in the soil environment normally occurs in the trivalent As (III) and pentavalent As (V) oxidation state. In soils and natural waters Arsenic typically occurs as weak triprotic oxyacids. In a reducing environment, arsenous acid dominates in the form of $H_3As^{III}O_3$ at wide range of values while the protonated $H_2As^{III}O_3^-$ forms only at pH > 9.0. At higher pH and in an oxidized environment, As (V) is present as $H_2AsO_4^-$ (pH< 7) or as $HAsO_4^{2-}$ (pH >7.0) (Bohn *et al.* 1979). The partitioning of arsenic between dissolved and solid phases could be controlled by adsorption (Hering and Knee, 2001). Reductive dissolution of iron phases in the sediment by proton assisted (acid), and ligand – promoted reductive dissolution are the several mechanism for the mobilization of adsorbed Arsenic in the sediment (Cornell and Schwert, 1996).

Materials and Methods

Study area:

Sundarban, the largest delta on earth in the esturine phase of the river Ganga is a unique climatic zone in a typical geographical situation ($20^0 32^/$ - $20^0 40^/$ N and $88^0 05^/$ - 89^0 E) at the coastal region of the Bay of Bengal. The land-occean boundary of the Sundaeban mangrove forest is highly irregular and criss- crossed by several rivers and waterways. Several discrete islands and lowlying intertidal zones are covered with thick mangrove forest. Hight of natural mangrove plants genera such as *Avicennia, Acanthus, Aegiceras, Bruguiera, Ceriops*, etc. >10 m is rare.

Surface water and pore water with sediment samples were collected every month from July, 2014 to June 2015 from the Sundarbans mangrove dominated Matla estuary at six station: Canning, Jharkhali, Godkhali, Sajnekhali, Bony camp, Haliday Island (Fig.1 map of sampling sites is attached). Arsenic species in surface and pore water were determined by AAS using hydride generation technique. Total Arsenic in solid phase was determined in freezed dried sample by digestion with $HF/HCl/HNO_3$. Suspended particulate matter was separated from the water samples by filtration through Millipore filter paper and were analysed for particulate Arsenic. Acid mixture (HF, HNO_3, HCl) for freeze dried sediment, suspended particulate matter samples for total arsenic analysis using Varian Hydride System-Vapor Generator (serial No. EL0405-314) coupled to Spectra AA 55B true Double Beam Atomic Absorption Spectrometer following methods as described by Loring and Rantala (1992) and Yamamoto *et al.*, 1985. Measurement of dissolved As (III) was performed by hydride generation at pH 4 using 5% potassium biphthalate (Barman *et al.*, 1977). The analytical methods for arsenic were checked before analyses of each batch of samples against standard samples procured from MERCK K GaA, Germany. Relative accuracy and coefficient of variation were 96.2% and 9.2%, respectively for arsenic.

Result and Discussion

The mean Arsenic concentrations varied in the tidal water from 5678 to13075ngL^{-1}, in pore water from 11438 to 17421 ngL^{-1}, in ground water from 7245 to 16799 ngL^{-1} and in sediment 2.15 to 3.85 mgkg^{-1}. Arsenic concentrations in tidal water demonstrated strong seasonal variations

Fig. 1 Map showing the station location

(Fig. 2), with a maximum of 13028±8876 ngL^{-1} during pre-monsoon and a minimum of 6882±4248 ngL^{-1}during post-monsoon and intermediate of 8628±6652 ngL^{-1} during monsoon. Dilution of coastal water could result decrease of arsenic with increasing water discharge in the monsoon season relative to pre-monsoon. Increased arsenic concentration with increasing salinity in the mixing zone of the Matla estuary (Fig.3) indicated that its source strength from mangrove ecosystem at the lower stretch of the estuary could be greater than that of river source.

Organic carbon and Eh varied downward decrease for six stations are common features from (0.855 to 0.305%) (Eh -25.9 to -235mV) (Fig. 4) indicates microbial- mediated oxidation of organic carbon (Canuel and Martens 1993). Elevated concentration of arsenic in the deeper layers relative to the surface (2.15- 3.85 $mgKg^{-1}$) (Fig.4) indicates that arsenic supply seems to have declined. Arsenic and organic matter could be co-deposited and microbial degradation of organic matter drives arsenic release from the sediment to pore water with less feedback of adsorption leading to its migration from sediment to overlying water.

Fig. 2 Seasonal variations of As (total) and As (III) in tidal, poreand ground water in the Matla estuary

Fig. 3 Salinity versus dissolved Arsenic (total) in the salinity gradient zone of the Matla estuary.

Fig. 4 Depth profile of As ($mgKg^{-1}$), Organic C(%) and Eh(mV)

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 167-189, 2016

Generation Mean Analysis to Determine and Partition the Components of Genetic Resistance to Root Rot in Sesame (*Sesamum indicum* L.)

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Published : 30.10.2017

Abstract

Sesame (*Sesamum indicum* L.) is an important oil yielding crop of the world and it is exposed to various bacterial and fungal diseases throughout its life cycle, causing huge losses all over the world. Among the major fungal diseases root rot caused by *Macrophomina phaseolina* (Tassi) Goid, is of primary concern. The nature of gene action governing root rot resistance were determined with nine genotypes, four with resistance and five with susceptible reactions to root rot. For this purpose five generations - P_1, P_2, F_1, F_2 and F_3 were analyzed in six cross-combinations. Scaling tests detected presence of epistasis for all traits within all six cross combinations. Dominance gene effects also played major role in controlling the genetic variance of trait seed yield/plant. However, additive gene effects appeared to be important for inheritance of some other yield related traits such as capsule length. Estimates of broad-sense heritability and genetic advance were significant and relatively consistent under both conditions for all the traits under study. The result suggested that both dominant and additive gene action were involved in resistance for root rot but due to higher magnitude of dominant gene effects, resistance to root rot appeared to be controlled mainly by dominance effects, therefore the parental lines could be utilized strategically in sesame breeding programs for root rot resistance.

Key words : Root rot; Generation mean analysis, *Macrophomina phaseolina,* Quantitative resistance, Scaling test, Sesame

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Introduction

The fungus *Macrophomina phaseolina* (Tassi) Goid has wide geographical distribution and is a causative agent of diseases of over 75 plant families with more than 500 plant species worldwide. The fungus attacks major economically important field crops although, there is a lack of effective control methods and genetic resistance for *this soil borne fungus* in most field crops including sesame (Mah *et al.* 2012). Sesame (*Sesamum indicum* L.) is an oldest oilseed crops of Pedaliaceae family and is mostly cultivated in tropical and subtropical regions of Asia, Africa and South America (Ashri 1998). The seed is of high quality due to presence of protein, vitamins, minerals and lignans and widely used as popular food and medicine (Moazzami and Kamal-Eldin 2006; Pandey *et al.* 2017). Sesame in Indian subcontinent represents wide genetic diversity for various agro-morphological traits (Kumar and Sharma, 2011; Pandey *et al*. 2013, 2015). The total area of sesame harvested in the world is currently 10819558 hectares with annual productivity of 5763 Hg/Ha (2014, UN FAO, data). In some parts of India, the reduction in crop yield and quality due to root rot is more than 30 % of the potential yield (Savaliya *et al.* 2015). High incidence of this disease during hot growing seasons has been reported to be associated with water stress, humidity and high temperatures (Khalili *et al.* 2016). At present, there is no effective

management approach available for root rot resistance. Moreover, development of resistant plants via genetic engineering is not feasible due to the lack of knowledge on the molecular processes occurred during *M. phaseolina* host interactions. Development of cultivars with inherent resistance is one of the most effective and economical means of controlling the root rot in sesame although there have been lack of information on the inheritance of resistance to root rot in sesame except very few (El-Bramawy and Shaban 2007). Gene action plays a crucial role in the choice of a suitable breeding method for improvement of quantitative characters. Generation mean analysis has been used to detect types of gene action involved in several quantitatively inherited traits including disease resistance (Dias *et al.* 2004). Information about nature and magnitude of gene actions involved in resistance for root rot can be useful for breeding high yielding resistant varieties in sesame against root rot. Therefore, the present study was designed to determine the types of gene action and to estimate the heritability for resistance to root rot under ûeld and greenhouse conditions for sesame.

Materials and Methods

Plant Materials

Four root rot resistant lines namely Tillotama, Uma, Rama and Savitri and five susceptible varieties VRI-1, Gujarat Til-2, NIC 8316, TKG-22 and OSC-593 were used as parents for the present study. Six crosses viz. Uma × Tillotama (R×R); Rama × Savitri (R×R); Rama × VRI-1 (R×S); Tillitama × Gujarat Til-2 (R×S); Uma × NIC-8316 (R×S) and TKG-22 × OSC-593 (S×S) were made to derive F_1 hybrids. On the same F_1s, F_2s and F_3s seeds were generated by self-pollination. The experimental material comprised of five generations (P_1, P_2, F_1, F_2 and F_3) derived from each of the six crosses was screened in Field Infected (FI) condition and Field Control (FC) condition at the farmers field at Nonaghata (latitude 23°42′ and longitude 88°44′, Nadia, West Bengal, India) and under Greenhouse Infected (GHI) condition and Greenhouse Control (GHC) conditions in the Department of Genetics and Plant Breeding, Institute of Agricultural Science for resistance to root rot during 2012–13.

Field Experiment

An experiment was conducted during the *Pre-kharif* 2012-13 to test the root rot severity percentage of five generations under field conditions. The field experiment was carried out in the farmer's field with a history of high natural infection at Nonaghata (Nadia district) of West Bengal, India. These lines were evaluated using a single susceptible check variety VRI-1, which has been previously tested for aggressiveness. The experimental layout was a complete randomized block design with three replications. The P_1, P_2 and F_1 were planted one plot per block, F_2 and F_3 planted in eight plots per block. Each row in a plot is of 3 meters length with of 40 cm × 10 cm spacing. Artificial inoculation and habitual local recommended agronomic practices were followed as described by Pandey *et al* 2012.

Greenhouse Experiment

Biological control experiment was carried out under greenhouse condition in the Department of Genetics and Plant Breeding, Institute of Agricultural Science during 2012-2013 to test the severity percentage under control condition following the method described by Pandey *et al* 2012. Some morphological characters such as germination % (GER%), number of primary branches/ plant (PB), plant height (PH), days to 50% flowering (DF),days to maturity (DM), 1000 seed weight (SW), number of capsules / plant (CP), capsule length (CL), number of seeds/ capsule (SC) and seed yield/plant (SY) were measured and recorded between treated and control. Each plant was visually assessed for disease infection using linear 0 to 5 scale. 0 = healthy and no symptoms (Immune). Percentage of Pre- Emergence Damping Off (PRE_{DOFF} %), Percentage of Post- Emergence Damping Off ($POST_{DOFF}$ %) and Percentage of Disease Incidence (DI %) was determined at the end of experiment the method described by Kavak and Boydak (2006).

Statistical Analysis

A generation mean analysis was performed on

the data in accordance to the procedure outlined by Mather and Jinks (1971). The data were tested for the adequacy of the additive-dominance model using the ABC Scaling Test (Mather 1949). The five parameters of five parameter model were estimated as follows:

$$m = \overline{F_2}$$

$$d = \tfrac{1}{2}\overline{P1} - \tfrac{1}{2}\overline{P2}$$

$$h = 1/6\ (\overline{4F_1} + \overline{12}F_2 - \overline{16}F_3)$$

$$i = \overline{P1} - \overline{F_2} + \tfrac{1}{2}(\overline{P1} - \overline{P2} + h) - \tfrac{1}{4}l$$

$$l = 1/3\ (\overline{16F_3} - \overline{24}F_2 + \overline{8}F_1)$$

Where, [m] = the mean of all generation, [d] = the sum of additive effects, [h] = the sum of dominance effects, [i] = the sum of additive × additive interaction (complementary), [l] = the sum of dominance × dominance interaction (duplicate). The genetic parameters [m], [d], [h], [i], [l] were tested for significance using a t-test.

Results and Discussion

Mean Performance of all the traits in six cross combination under Field and Greenhouse conditions

The mean performance along with standard error under both greenhouse and field condition for the all six cross combinations are given in Table 1-6. For all the crosses DI% was higher in GHI condition than FI condition and hence infected genotypes yielded more in field than in greenhouse. For most of the crosses F_1 yielded more than F_2 under all the four experimental condition except for few crosses such as cross combinations–III, where under infected condition F_3 yielded more than F_1 and for cross combination–V under GHI condition where, F_2 and F_3 yielded more than F_1 and similarly, in cross combination–VI, F_3 yielded more than F_1 under GHI condition. This may be due to the reason that DI% in F_2 and F_3 was lower than that was prevalent during F_1 generation resulting in more yield in F_2 and F_3 than F_1. From the screening test it may be concluded that out of six crosses highest DI% in F_1 (>80%), F_2 (>75%), and F_3 (>75%), was recorded in cross combination-IV under GHI condition. Whereas, least DI% was estimated in cross combination-V followed by cross combination-III under FI condition. For both the cross combinations-V and III, DI% recorded to be less than 25% in F_1 generation and less than 20% for both F_2 and F_3 generations. These crosses might be helpful for breeding program due to their stability and consistency for disease resistance; similar findings in other crosses for same disease have been reported by El- Marzoky (1982). High SY in F_1 (16.96), F_2 (16.22) and F_3 (16.43) was recorded in cross combination–V under infected condition. While lowest SY in F_1 (5.46), F_2 (3.62) and F_3 (3.52) was recorded under infected condition of cross combination-I and IV respectively. High SY under normal condition in F_1 (22.99), F_2 (21.55) and F_3 (21.92) was recorded in cross combination–V, while lowest SY in F_1 (7.51), F_2 (5.95) and F_3 (5.98) was recorded under control condition of cross combination-IV respectively. Under GHC conditionin the advance segregating generations namely F_2 and F_3, the plants of cross combination–I were found to be shorter in height than parents with high CP and average SY. While, the population of cross combination–II were of short duration, high yielding with high SW (>3g). The cross combination–III and VI showed higher CP than the parents whereas, populations of cross combination–IV were inferior to parents. Cross combination–V was very early maturing cross having very high CP. Under FC condition the advance generation population of cross combination I and III were short height plants with high SY over parents. F_2 and F_3 of cross combination–II were less branching and high yielding. Poor yielding lines than the parents were observed in cross combination- IV. The most promising lines with high SY and CP were recorded in cross combination-V. Short duration segregating lines were observed in F_2 and F_3 generations of cross combination–VI.

Estimates of Genetic Parameters under both Field and Greenhouse Condition for Six Crosses

The genetic parameters under both greenhouse and field condition for the all six cross combinations are presented in Table 7 for control condition and in Table 8 for infected condition. For cross combination-I, II, III, IV and VI high GCV and PCV were found for SC, CP and CL. High heritability with high GA was

TABLE 1. Means and standard error of five generations of Cross-I under controlled and infected conditions in greenhouse and field

Population	Environments	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
I S														
	FI	11.34±0.19	15.27±0.32	19.53±0.15	-	75.00±0.60	2.09±0.04	38.00±0.83	92.00±0.73	2.33±0.03	31.77±0.32	52.23±0.26	2.97±0.01	6.53±0.16
	FC	-	-	-	88.44±0.06	83.83±0.48	2.34±0.06	35.00±0.82	91.0±0.76	2.27±0.07	50.01±0.41	54.03±0.42	3.12±0.02	9.69±0.17
P_1	GHI	13.2±0.24	23.93±0.11	45.94±0.15	-	64.92±0.39	3.51±0.08	37.00±0.96	92.00±0.80	1.78±0.01	28.97±0.18	48.22±0.12	2.85±0.03	4.80±0.21
	GHC	-	-	-	93.56±0.29	67.74±0.32	2.00±0.02	35.00±0.51	92.00±0.61	2.02±0.02	37.81±0.17	54.67±0.18	2.91±0.02	7.5±0.14
	FI	9.13±0.21	10.90±0.36	16.34±0.13	-	80.83±0.42	2.38±0.05	41.00±0.75	94.00±0.71	2.38±0.4	51.23±0.33	59.87±0.28	3.00±0.01	8.60±0.14
	FC	-	-	-	88.24±0.07	86.85±0.34	2.19±0.06	41.00±0.70	90.00±0.68	2.55±0.05	69.52±0.39	61.82±0.39	3.02±0.01	11.62±0.16
P_2	GHI	0.01±0.14	13.98±0.12	24.08±0.17	-	61.62±0.42	2.01±0.07	37.00±0.83	97.00±0.79	1.80±0.02	26.00±0.16	48.18±0.10	2.04±0.02	4.40±0.21
	GHC	-	-	-	93.180.32	67.590.30	2.01±0.02	37.00±0.56	93.00±0.63	1.86±0.03	37.76±0.19	51.61±0.17	2.49±0.01	6.76±0.13
	FI	24.28±0.25	27.20±0.31	46.66±0.13	-	68.76±0.38	1.42±0.04	34.00±0.67	89.00±0.67	2.21±0.03	55.92±0.34	65.10±0.23	2.93±0.02	9.14±0.14
	FC	-	-	-	88.52±0.08	80.07±0.46	2.08±0.05	32.00±0.87	87.00±0.74	2.44±0.05	74.90±0.38	68.08±0.38	3.03±0.01	13.78±0.15
F_1	GHI	39.82±0.31	33.72±0.10	64.31±0.19	-	59.60±0.34	2.20±0.08	36.00±0.86	92.00±0.72	2.02±0.01	42.05±0.17	61.50±0.19	2.75±0.01	5.46±0.17
	GHC		-	-	88.280.24	63.840.31	1.98±0.02	33.00±0.53	90.00±0.56	2.45±0.03	49.87±0.18	65.38±0.16	2.86±0.02	8.03±0.11
	FI	30.88±0.21	34.18±0.33	55.43±0.20	-	68.67±0.31	1.96±0.04	34.00±0.76	91.00±0.71	2.20±0.04	53.63±0.33	59.75±0.32	2.700±0.02	6.86±0.13
	FC	-	-	-	86.35±0.10	80.01±0.30	2.08±0.06	31.00±0.64	89.00±0.73	2.38±0.07	71.82±0.41	62.98±0.43	2.38±0.03	11.71±0.14
F_2	GHI	35.32±0.31	41.86±0.11	64.32±0.14	-	59.94±0.43	2.15±0.09	35.00±0.85	92.00±0.76	2.15±0.02	38.69±0.16	54.43±0.14	2.69±0.01	4.33±0.17
	GHC	-	-	-	88.170.35	63.900.38	2.02±0.02	33.000.57	91.00±0.77	2.380.02	47.85±0.18	59.64±0.16	2.74±0.01	6.99±0.11
	FI	33.05±0.24	37.71±0.39	57.71±0.16	-	78.63±0.39	2.07±0.03	34.00±0.77	91.00±0.65	2.40±0.03	51.88±0.36	63.74±0.21	2.75±0.02	6.98±0.14
	FC	-	-	-	87.34±0.05	77.48±0.44	2.06±0.05	32.00±0.65	89.00±0.56	2.42±0.06	73.67±0.39	61.80±0.32	2.78±0.03	12.06±0.16
F_3	GHI	36.74±0.29	45.05±0.08	69.12±0.18	-	59.68±0.48	2.16±0.08	35.00±0.83	93.00±0.63	2.13±0.02	36.12±0.21	54.49±0.12	2.73±0.02	4.26±0.18
	GHC	-	-	-	87.510.30	63.87±0.31	2.02±0.02	33.00±0.55	91.00±0.56	2.30±0.03	46.89±0.18	59.68±0.18	2.73±0.02	7.02±0.14

*P<0.05, **P<0.01.

TABLE 2. Means and standard error of five generations of Cross-II under controlled and infected conditions in greenhouse and field

Population	Environments	PRE_{DOFF}%	$POST_{DOFF}$%	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
I S														
	FI	25.05±0.09	13.63±0.06	20.21±0.12	-	85.43±0.20	3.04±0.20	38.00±0.75	95.00±0.84	1.87±0.01	43.87±0.23	51.06±0.18	3.00±0.01	7.47±0.18
	FC	-	-	-	84.16±0.04	93.56±0.14	3.44±0.54	36.00±0.08	88.00±0.90	1.94±0.50	64.47±0.02	51.89±0.60	3.02±0.48	10.60±0.18
P_1	GHI	40.02±0.12	17.56±0.07	47.23±0.15	-	63.00±0.19	4.43±0.08	45.00±0.63	98.00±0.82	1.82±0.02	26.17±0.02	50.03±0.02	2.75±0.01	3.66±0.11
	GHC	-	-	-	86.26±0.08	70.72±0.57	3.99±0.04	43.00±0.63	97.00±0.76	1.85±0.23	35.74±0.26	57.45±0.27	2.94±0.01	6.95±0.16
	FI	51.16±0.08	21.16±0.05	75.99±0.11	-	97.03±0.22	2.59±0.18	41.00±0.67	97.00±0.76	2.15±0.02	28.91±21	46.88±0.17	2.50±0.02	2.79±0.12
	FC	-	-	-	83.64±0.05	112.50±0.13	2.43±o.42	48.00±0.05	96.00±0.82	2.17±0.11	59.99±0.04	47.62±0.43	2.75±0.34	7.02±0.14
P_2	GHI	74.40±0.11	26.23±0.06	93.99±0.13	-	68.77±0.17	0.00±0.0	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	GHC	-	-	-	86.64±0.07	102.04±0.43	2.02±0.04	46.00±0.52	98.00±0.65	2.01±0.03	36.80±0.03	43.03±0.21	2.63±0.04	4.84±0.15
	FI	21.09±0.01	22.54±0.07	44.35±0.13	-	97.10±0.23	1.89±0.23	32.33±0.67	89.67±0.56	2.18±0.03	101.95±0.2	54.06±0.11	3.00±0.42	11.00±0.11
	FC	-	-	-	84.62±0.06	109.38±0.14	2.31±0.43	31.00±0.07	87.00±0.56	2.35±0.42	125.32±0.18	56.38±0.37	3.22±0.03	17.30±0.16
F_1	GHI	33.33±0.13	30.26±0.08	55.79±0.16	-	86.08±0.22	2.36±0.03	35.00±0.43	93.00±0.61	1.99±0.21	86.14±0.04	48.72±0.01	3.05±0.02	8.57±0.15
	GHC	-	-	-	83.77±0.08	90.83±0.55	2.06±0.02	33.00±0.41	91.00±0.72	2.37±0.12	98.82±0.03	54.74±0.23	3.15±0.02	12.64±0.14
	FI	25.61±0.09	21.13±0.05	41.62±0.12	-	59.67±0.26	2.23±0.21	32.00±0.43	89.00±0.59	2.14±0.06	92.89±0.18	61.99±0.14	3.10±0.01	9.65±0.14
	FC	-	-	-	81.21±0.05	70.70±0.13	2.46±0.39	31.33±0.11	87.3±0.65	2.32±0.41	121.20±0.03	64.04±0.34	3.2±0.32	17.00±0.13
F_2	GHI	28.12±0.11	29.55±0.06	50.79±0.14	-	49.63±0.21	2.51±0.05	34.00±0.48	90.00±0.71	2.06±0.09	82.68±0.04	56.73±0.02	3.11±0.04	7.48±0.10
	GHC	-	-	-	83.48±0.06	54.64±0.54	2.39±0.03	32.00±0.39	89.00±0.79	2.30±0.05	94.80±0.17	51.97±0.17	3.21±0.05	11.77±0.09
	FI	24.93±0.08	21.14±0.06	40.65±0.13	-	59.16±0.22	2.23±0.19	33.00±0.63	90.00±0.88	2.14±0.06	93.89±0.31	61.87±0.16	3.13±0.03	9.83±0.15
	FC	-	-	-	80.77±0.04	72.46±0.18	2.38±0.37	31.00±0.12	87.00±0.77	2.34±0.33	121.98±0.05	64.20±0.45	3.26±0.38	17.16±0.13
F_3	GHI	28.07±0.12	29.39±0.06	50.37±0.14	-	49.75±0.13	2.40±0.07	34.00±0.55	91.00±0.68	2.13±0.11	83.72±0.06	56.68±0.02	3.14±0.07	7.61±0.12
	GHC	-	-	-	83.67±0.07	55.49±0.54	2.35±0.04	32.00±0.45	89.00±0.87	2.31±0.03	97.03±0.15	52.06±0.21	3.19±0.03	12.14±0.10

*P<0.05, **P<0.01.

TABLE 3. Means and standard error of five generations of Cross-III under controlled and infected conditions in greenhouse and field

Population	Environments	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
I S														
	FI	9.08±0.08	10.90±0.29	16.40±0.10	-	80.70±0.45	2.41±0.03	41.00±0.80	94.00±0.80	2.41±0.03	50.93±0.24	59.87±0.30	3.00±0.01	8.60±0.17
	FC	-	-	-	88.24±0.03	86.52±0.29	2.32±0.07	40.00±0.63	89.00±0.91	2.55±0.05	69.52±0.33	61.82±0.42	3.02±0.02	11.62±0.13
P_1	GHI	0.00±0.0	13.98±0.14	24.05±0.11		51.59±0.32	2.03±0.02	38.00±0.39	97.00±0.78	1.80±0.02	26.01±0.28	48.180.23	2.02±0.01	4.40±0.30
	GHC	—	-	-	93.18±0.28	67.59±0.34	2.03±0.01	37.00±0.63	90.00±0.93	1.84±0.05	37.33±0.38	51.94±0.32	2.49±0.02	6.76±0.19
	FI	48.92±0.15	29.87±0.21	59.74±0.09	-	74.05±0.42	2.11±0.02	35.00±0.56	93.00±0.54	2.22±0.04	36.00±0.34	61.09±0.33	3.68±0.01	7.47±0.14
	FC	-	-	-	89.89±0.04	83.61±0.42	2.36±0.05	32.00±0.34	89.00±0.67	2.16±0.04	61.40±0.31	58.520.34	3.80±0.04	12.86±0.13
P_2	GHI	59.73±0.19	50.17±0.17	85.92±0.06	-	68.29±0.24	1.99±0.04	33.00±0.43	88.00±0.87	1.91±0.06	19.60±0.37	53.54±0.28	3.44±0.02	4.57±0.23
	GHC	-	-	-	93.22±0.23	70.74±0.32	2.02±0.04	33.00±0.57	90.00±0.50	2.12±0.03	41.8±00.23	59.90±0.21	3.48±0.03	9.96±0.16
	FI	15.51±0.04	12.63±0.11	29.25±0.08		98.56±0.26	1.10±0.07	32.00±0.32	89.00±0.51	2.42±0.02	99.14±0.22	66.89±0.26	2.83±0.03	15.03±0.14
	FC	-	-	-	89.24±0.06	109.39±0.36	2.14±0.05	29.00±0.59	87.00±0.54	2.55±0.01	120.5±0.20	68.62±0.37	2.97±0.02	21.22±0.13
F_1	GHI	20.08±0.16	16.61±0.09	46.42±0.10	-	85.74±0.33	1.29±0.02	34.00±0.43	94.00±0.76	2.22±0.04	98.2±0.31	60.81±0.33	2.74±0.02	10.86±0.26
	GHC				89.26±0.31	91.36±0.21	1.02±0.04	33.00±0.34	92.00±0.63	2.62±0.03	106.01±0.3	65.41±0.45	2.85±0.02	14.89±0.14
	FI	10.08±0.13	10.07±0.04	19.43±0.11	-	61.58±0.23	1.74±0.06	32.00±0.52	91.00±0.63	2.25±0.02	88.88±0.11	62.2±0.37	3.50±0.01	14.96±0.14
	FC	-	-	-	86.97±0.04	63.87±0.27	2.20±0.06	30.00±0.37	88.00±0.82	2.40±0.02	118.79±0.3	64.68±0.43	3.65±0.03	20.19±0.13
F_2	GHI	19.12±0.15	16.18±0.13	36.07±0.14	-	42.28±0.34	2.18±0.03	34.00±0.64	92.00±0.76	2.15±0.05	80.36±0.41	58.76±0.22	3.41±0.02	10.05±0.15
	GHC	-	-	-	89.78±0.22	49.94±0.41	2.09±0.02	31.00±0.39	90.00±0.81	2.35±0.01	93.64±0.28	62.50±0.35	3.51±0.01	14.97±0.15
	FI	10.45±0.15	10.23±0.12	19.48±0.06	-	62.74±0.39	1.81±0.01	32.00±0.76	91.00±0.55	2.32±0.01	89.01±0.26	62.93±0.21	3.54±0.01	15.18±0.13
	FC	-	-	-	86.93±0.03	64.64±0.23	2.15±0.06	31.00±0.34	89.00±0.76	2.48±0.02	120.83±0.4	65.21±0.43	3.73±0.01	20.64±0.13
F_3	GHI	19.38±0.05	17.00±0.14	36.20±0.10	-	42.96±0.22	2.29±0.05	34.00±0.75	93.00±0.92	2.21±0.02	80.94±0.40	59.00±0.38	3.47±0.02	10.23±0.18
	GHC	-	-	-	90.74±0.22	50.86±0.33	2.10±0.02	32.00±0.43	91.00±0.43	2.47±0.01	93.11±0.31	62.80±0.36	3.57±0.01	15.26±0.20

*P<0.05, **P<0.01.

TABLE 4. Means and standard error of five generations of Cross-IV under controlled and infected conditions in greenhouse and field

Population I	Environments S	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	FI	25.16±0.12	13.65±0.02	20.21±0.14	-	85.43±0.27	3.14±0.05	38.00±0.47	96.00±0.42	1.86±0.03	43.60±0.18	51.06±0.09	3.00±0.01	7.47±0.15
	FC	-	-	-	84.31±0.07	93.56±0.47	3.30±0.06	36.00±0.68	87.00±0.55	1.98±0.02	64.14±0.50	51.89±0.34	3.02±0.01	10.60±0.19
P_1	GHI	40.02±0.12	17.56±0.07	47.29±0.15	-	62.97±0.19	4.36±0.08	45.00±0.63	98.00±0.82	1.76±0.02	26.17±0.21	50.03±0.25	2.75±0.01	3.66±0.11
	GHC	-	-	-	86.26±0.15	70.72±0.87	4.07±0.06	43.00±0.55	97.00±0.55	1.83±0.03	35.74±0.27	57.66±0.35	2.96±0.03	6.95±0.16
	FI	34.01±0.13	10.30±0.05	36.38±0.15	-	75.46±0.23	0.98±0.05	34.00±0.44	92.00±0.56	2.15±0.02	29.62±0.45	60.37±0.14	2.92±0.02	5.12±0.12
	FC	-	-	-	89.81±0.13	79.85±0.40	1.08±0.06	31.00±0.65	88.00±0.64	2.26±0.03	50.98±0.25	63.87±0.35	2.96±0.01	9.13±0.14
P_2	GHI	39.11±0.11	12.28±0.04	48.44±0.14	-	51.90±0.34	4.51±0.08	36.00±0.58	90.00±0.53	1.59±0.02	25.97±0.73	47.75±0.24	2.00±0.01	3.68±0.13
	GHC	-	-	-	93.39±0.06	61.36±0.57	1.91±0.03	35.00±0.87	90.00±0.53	1.97±0.04	34.98±0.23	44.86±0.35	2.48±0.02	5.95±0.15
	FI	43.40±0.12	28.53±0.04	60.31±0.13	-	79.60±0.35	1.75±0.04	36.00±0.45	94.00±0.75	1.85±0.02	59.03±0.43	50.12±0.15	2.85±0.02	5.58±0.14
	FC	-	-	-	81.16±0.08	91.00±0.25	2.00±0.04	34.00±0.65	93.00±0.34	1.99±0.01	72.74±0.37	50.99±0.45	2.99±0.03	9.90.164±
F_1	GHI	60.63±0.14	33.58±0.03	80.14±0.17		56.52±0.15	2.52±0.06	39.00±0.45	98.00±0.74	1.83±0.02	40.61±0.45	45.89±0.34	2.70±0.03	5.63±0.13
	GHC	-	-	-	81.32±0.11	60.80±0.79	2.15±0.07	36.00±0.56	96.00±0.57	1.91±0.04	47.27±0.45	48.48±0.24	2.90±0.01	7.51±0.13
	FI	39.52±0.15	36.65±0.06	61.82±0.11	-	56.78±0.22	1.71±0.08	35.00±0.25	93.00±0.57	1.78±0.02	41.07±0.34	46.44±0.14	2.83±0.02	4.40±0.14
	FC	-	-	-	78.64±0.12	68.09±0.42	2.03±0.03	32.00±0.54	91.00±0.38	2.00±0.04	68.52±0.26	48.65±0.25	2.97±0.02	8.63±0.15
F_2	GHI	42.80±0.11	41.82±0.04	77.51±0.12	-	40.15±0.11	2.20±0.03	38.00±0.72	96.00±0.64	1.53±0.05	33.45±0.34	41.67±0.43	2.80±0.02	3.52±0.16
	GHC	-	-	-	82.36±0.13	48.80±0.64	2.01±0.02	35.00±0.63	93.00±0.24	1.99±0.04	42.24±0.43	45.77±0.32	2.89±0.02	5.95±0.11
	FI	41.40±0.17	37.82±0.04	62.44±0.12	-	56.83±0.13	1.86±0.04	35.00±0.64	94.00±0.546	1.88±0.06	40.93±0.25	46.26±0.11	2.78±0.02	4.12±0.12
	FC	-	-	-	79.06±0.15	68.47±0.34	2.06±0.03	33.00±0.55	92.00±0.47	2.11±0.02	67.66±0.45	47.98±0.23	2.94±0.01	8.72±0.16
F_3	GHI	43.27±0.11	42.5±0.07	78.15±0.09	-	42.31±0.60	2.19±0.05	38.00±0.73	97.00±0.47	1.63±0.02	33.87±0.35	41.52±0.42	2.73±0.01	3.41±0.15
	GHC	-	-	-	82.93±0.16	48.86±0.12	2.04±0.04	36.00±0.55	94.00±0.53	1.92±0.02	41.77±0.75	45.80±0.32	2.84±0.03	5.98±0.15

*P<0.05, **P<0.01.0.01

TABLE- 5. Means and standard error of five generations of Cross-V under controlled and infected conditions in greenhouse and field

Population I	Environments S	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	FI	11.27±0.05	15.27±0.04	19.47±0.07	-	75.00±0.45	2.00±0.01	37.00±0.33	92.00±0.71	2.35±0.04	31.60±0.34	52.23±0.05	2.97±0.01	6.53±0.13
	FC	-	-	-	88.38±0.06	83.36±0.35	2.34±0.05	34.00±0.76	91.00±0.63	2.41±0.03	50.01±0.31	54.03±0.34	3.12±0.02	9.69±0.13
P_1	GHI	13.20±0.14	23.93±0.14	45.94±0.36	-	64.92±0.31	3.47±0.08	36.00±1.0	92.00±0.82	1.78±0.06	28.98±0.27	48.37±0.12	2.86±0.01	4.80±0.14
	GHC	-	-	-	93.44±0.16	67.74±0.35	2.13±0.08	35.00±0.59	92.00±0.69	2.07±0.05	37.83±0.41	54.90±0.27	2.91±0.01	7.50±0.11
	FI	56.68±0.07	26.50±0.05	69.09±0.10	-	85.51±0.32	2.12±0.02	39.00±0.56	96.00±0.67	1.80±0.05	41.94±0.35	56.85±022	3.09±0.02	5.44±0.12
	FC		-	-	85.11±0.08	106.23±0.34	1.64±0.03	36.00±0.46	93.00±0.86	1.78±0.05	69.30±0.43	48.83±0.32	3.03±0.01	9.78±0.13
P_2	GHI	79.47±0.17	33.09±0.11	88.68±0.31	-	72.07±0.25	2.68±0.07	46.00±0.36	91.00±0.67	0.00±0.00	0.00±0.00	0.00±0.0	0.00±0.0	0.00±0.0
	GHC	-	-	-	91.15±0.15	92.00±0.42	3.49±0.07	39.00±0.64	90.00±0.75	1.72±0.05	31.09±0.45	50.51±0.23	2.80±0.03	5.26±0.11
	FI	9.18±0.06	14.38±0.05	24.66±0.06	-	84.00±0.24	2.99±0.04	32.00±0.53	90.00±0.68	2.29±0.04	115.2±0.45	68.42±0.23	2.92±0.03	16.96±0.2
	FC	-	-	-	86.26±0.09	94.97±0.43	3.59±0.05	30.00±0.64	86.00±0.57	2.40±0.04	145.8±0.34	70.52±0.12	3.01±0.02	22.99±0.2
F_1	GHI	13.18±0.16	23.02±0.10	43.04±0.23	-	88.11±0.24	3.27±0.03	35.00±0.57	93.00±0.65	1.93±0.050	99.27±0.23	51.27±0.24	2.88±0.01	11.02±0.1
	GHC	-	-	-	86.67±0.14	93.65±0.34	2.96±0.03	32.00±0.47	90.00±0.74	2.32±0.67	109.64±0.23	68.58±0.22	2.92±0.01	18.03±0.1
	FI	9.09±0.07	10.27±0.05	17.56±0.06	-	58.90±0.25	1.89±0.04	33.00±0.46	90.00±0.47	2.35±0.57	108.87±0.32	66.26±0.34	2.97±0.02	16.22±0.2
	FC	-	-	-	84.55±0.15	67.88±0.35	2.11±0.03	31.00±0.54	86.00±0.65	2.56±0.75	140.81±0.64	68.70±0.23	3.00±0.02	21.55±0.2
F_2	GHI	12.00±0.19	15.18±0.15	29.22±0.23	-	43.89±0.34	2.22±0.04	35.00±0.36	91.00±0.65	2.31±0.58	96.91±0.45	60.98±0.23	2.89±0.01	11.94±0.1
	GHC	-	-	-	87.92±0.13	48.69±0.26	2.14±0.03	32.00±0.46	89.00±0.68	2.53±0.75	108.75±0.54	65.84±0.34	2.96±0.01	17.68±0.2
	FI	9.02±0.04	10.15±0.11	17.44±0.04	-	58.74±0.34	1.91±0.04	33.00±0.56	91.00±0.75	2.32±0.47	112.76±0.34	66.58±0.26	3.00±0.01	16.43±0.2
	FC	-	-	-	84.75±0.13	67.99±0.48	2.19±0.03	31.00±0.35	87.00±0.74	2.57±0.54	142.52±0.34	68.36±0.43	3.00±0.02	21.92±0.1
F_3	GHI	11.90±0.17	15.00±0.14	29.12±0.24	-	43.75±0.36	2.37±0.04	35.00±0.45	91.00±0.57	2.30±0.35	97.00±0.43	61.03±0.25	2.93±0.02	12.3±0.12
	GHC	-	-	-	88.05±0.08	49.02±0.36	2.05±0.06	33.00±0.53	90.00±0.75	2.49±0.54	109.66±0.34	65.43±0.34	2.96±0.02	17.81±0.2

*P<0.05, **P<0.01.

TABLE- 6. Means and standard error of five generations of Cross-VI under controlled and infected conditions in greenhouse and field

Population IS	Environments	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	FI	18.28±0.12	22.07±0.07	61.34±0.07	-	74.05±0.38	2.06±0.04	35.00±0.69	94.00±0.67	2.17±0.05	20.91±0.32	58.84±0.08	3.49±0.01	4.91±0.17
	FC	-	-	-	86.60±0.08	90.16±0.37	2.01±0.05	32.00±0.30	90.00±0.38	2.12±0.01	51.00±0.16	59.32±0.12	3.56±0.01	11.71±0.20
P_1	GHI	19.72±0.25	26.99±0.19	86.40±0.23	-	57.58±0.28	1.92±0.04	35.00±0.44	89.00±0.55	1.63±0.03	16.71±0.28	42.74±0.19	3.26±0.01	3.01±0.12
	GHC	-	-	-	93.33±0.08	69.65±0.50	1.96±0.08	35.00±0.63	90.00±0.50	1.82±0.05	35.87±0.17	50.98±0.22	3.35±0.01	7.15±0.14
	FI	43.21±0.16	32.35±0.04	56.15±0.11	-	83.29±0.34	1.98±0.05	38.00±0.34	92.00±0.34	2.30±0.05	25.06±0.16	53.5±0.12	3.52±0.01	4.87±0.14
	FC	-	-	-	82.25±0.06	103.0±0.22	2.82±0.06	34.00±0.42	91.00±0.25	2.33±0.03	52.84±0.28	54.44±0.15	3.89±0.02	10.86±0.27
P_2	GHI	59.96±0.31	45.97±0.20	79.38±0.12	-	84.08±0.34	1.56±0.05	43.00±0.25	90.00±0.35	0.00±0.0	0.00±0.0	0.00±0.0	0.00±0.00	0.00±0.00
	GHC	-	-	-	86.65±0.06	83.51±0.53	3.01±0.04	37.00±0.24	91.00±0.42	2.16±0.03	38.81±0.26	60.83±0.23	3.50.020±	7.96±0.21
	FI	31.41±0.17	19.45±0.08	50.25±0.09	-	75.25±0.245	0.00±0.00	30.00±0.35	86.00±0.51	2.53±0.02	67.74±0.38	66.52±0.21	3.83±0.01	9.96±0.24
	FC	-	-	-	83.17±0.05	87.90±0.53	0.99±0.07	29.00±0.36	84.00±0.27	2.60±0.03	86.02±0.24	68.36±0.26	4.01±0.01	17.79±0.16
F_1	GHI	40.63±0.23	22.77±0.22	66.87±0.10	-	66.12±0.42	1.26±0.06	34.00±0.42	88.0±-0.47	2.12±0.04	49.70±0.16	62.15±0.21	3.74±0.01	8.84±0.15
	GHC	-	-	-	83.35±0.05	60.14±±0.53	0.95±0.06	32.00±0.46	87.00±0.67	2.54±0.04	60.83±0.15	67.17±0.22	3.93±0.01	13.89±0.19
	FI	30.55±0.14	26.25±0.15	45.37±0.12	-	49.91±0.25	2.39±0.03	32.00±0.36	88.00±0.47	2.23±0.01	55.00±0.37	62.38±0.31	3.96±0.02	9.41±0.14
	FC	-	-	-	81.46±0.04	61.24±0.56	2.66±0.01	29.00±0.26	85.00±0.38	2.50±0.01	82.83±0.36	64.82±0.34	4.09±0.02	16.84±0.16
F_2	GHI	37.60±0.22	29.91±0.32	49.97±0.14	-	39.75±0.63	2.61±0.06	34.00±0.52	89.00±0.44	2.22±0.02	46.17±0.29	58.13±0.12	3.87±0.03	8.76±0.22
	GHC	-	-	-	83.76±0.05	45.82±0.63	2.54±0.01	31.00±0.36	87.00±0.34	2.45±0.03	58.87±0.45	62.74±0.16	3.96±0.02	12.60±0.30
	FI	31.60±0.10	26.27±0.23	45.09±0.23	-	61.3±0.35	2.22±0.02	33.00±0.26	89.00±0.22	2.27±0.01	56.59±0.15	62.37±0.18	3.94±0.04	9.94±0.15
	FC	-	-	-	83.63±0.06	74.95±0.53	2.58±0.02	29.00±0.26	86.00±0.16	2.46±0.01	83.07±0.16	64.64±0.13	3.98±0.01	17.23±0.14
F_3	GHI	37.63±0.32	29.85±0.12	49.79±0.22	-	49.91±0.33	2.52±0.02	34.00±0.34	90.00±0.17	2.26±0.01	46.86±0.18	58.15±0.19	3.91±0.02	9.23±0.17
	GHC	-	-	-	85.23±0.11	54.8±0.54	2.45±0.02	32.00±0.24	88.00±0.25	2.47±0.01	59.78±0.21	63.36±0.15	3.88±0.02	12.83±0.09

*P<0.05, **P<0.01.

TABLE- 7. Estimates of genetic parameters of six crosses for ten characters under normal field and greenhouse condition

	GENETIC PARAMETERS	GER%		PH		PB		DF		DM		CL		CP		SC		SW		SY	
		FC	GHC	FC	GHC	FC	GHC	FC	GHC	FC	GHC	FC	GHC	FC	GHC	FC	GHC	FC	GHC	FC	GHC
Cross-1	PCV %	3.30	1.05	3.21	4.52	1.42	6.33	5.598	12.23	1.567	1.74	11.533	5.16	13.193	15.09	9.087	8.17	5.995	4.93	7.249	12.47
	GCV%	3.28	1.05	3.160	4.46	0.55	5.07	5.292	11.80	1.335	1.40	11.458	3.62	13.184	15.07	9.079	8.13	5.912	4.84	6.808	12.34
	H^2	0.98	0.99	0.965	0.97	0.14	0.64	0.893	0.93	0.725	0.64	0.987	0.49	0.998	0.99	0.998	0.98	0.972	0.96	0.882	0.97
	GA	6.05	1.90	4.182	7.42	0	0.16	3.573	8.02	2.149	2.06	0.513	0.11	11.951	21.04	10.87	10.30	0.325	0.28	0.955	2.961
	GAM %	6.71	2.16	6.39	9.09	0	7.81	10.44	23.46	2.35	2.31	23.29	4.85	27.13	31.01	18.68	16.68	11.83	9.90	13.15	25.15
Cross-2	PCV %	1.829	2.12	28.351	21.54	31.94	18.43	18.68	20.79	4.679	4.26	10.522	7.97	45.75	33.74	10.46	12.95	8.178	7.08	36.61	34.36
	GCV%	1.826	2.12	28.336	21.53	31.87	18.00	18.57	20.56	4.571	4.20	10.439	7.80	45.75	33.73	10.44	12.90	8.163	7.04	36.55	34.33
	H^2	99.60	0.99	99.89	0.99	99.57	0.953	98.78	0.977	95.46	0.97	98.42	0.95	99.99	0.99	99.61	0.993	99.62	0.98	99.67	0.998
	GA	3.182	3.63	43.606	40.66	1.678	0.940	14.29	14.85	8.593	7.63	0.731	0.35	68.45	71.85	11.13	15.06	0.500	0.44	7.269	9.763
	GAM%	3.75	4.38	58.34	44.33	65.49	36.09	39.43	41.87	9.25	8.57	33.71	15.7	94.24	72.87	21.47	26.50	68.53	14.2	75.18	70.66
Cross-3	PCV %	2.074	1.50	25.714	22.94	25.30	5.73	7.410	14.00	1.978	1.41	13.638	6.98	43.33	30.57	8.563	6.00	15.21	11.78	31.02	26.13
	GCV%	2.038	1.50	25.706	22.94	25.28	4.10	7.042	13.80	1.528	0.61	13.345	6.51	43.38	30.56	8.538	5.94	15.19	11.75	30.96	26.11
	H^2	0.965	0.99	0.999	0.99	0.997	0.51	0.903	0.971	0.957	0.19	0.957	0.86	0.99	0.99	0.994	0.98	0.996	0.994	0.995	0.998
	GA	3.764	2.72	34.991	38.57	0.964	0.13	4.632	9.193	2.222	0.49	0.611	0.30	66.382	61.85	10.61	7.73	0.992	0.831	7.871	9.194
	GAM %	4.12	3.09	52.93	47.24	52.05	5.81	13.95	28.37	2.45	0.55	26.79	12.6	89.24	62.96	17.53	12.13	31.19	24.19	63.64	53.12
Cross-4	PCV %	5.762	5.590	16.14	15.01	37.82	37.87	9.318	6.099	3.015	2.901	3.686	0.06	12.607	12.85	10.91	12.28	6.911	1.24	11.41	9.14
	GCV%	5.758	5.589	16.03	14.98	37.66	37.68	9.139	5.563	2.926	2.801	2.998	5.83	12.580	12.81	10.88	12.25	6.706	0.95	10.99	8.89
	H^2	0.998	0.999	0.987	0.997	0.991	0.997	0.961	0.990	0.942	0.832	0.661	0.93	0.995	0.923	0.993	0.994	0.941	0.99	0.927	0.59
	GA	10.104	9.507	19.07	24.74	1.882	1.616	26.305	3.498	4.476	5.044	0.002	0.23	10.446	17.06	10.83	13.27	0.374	0	1.409	1.67
	GAM %	11.85	11.51	32.82	30.86	77.25	77.17	71.09	10.53	4.76	5.59	0.10	11.3	25.85	26.32	22.33	25.19	13.29	0	21.78	17.81
Cross-5	PCV %	2.984	1.844	31.385	19.98	25.204	30.89	8.104	7.78	1.550	3.39	15.253	13.99	51.758	42.14	12.89	16.01	2.423	1.871	47.75	39.71
	GCV%	2.976	1.842	31.378	19.97	24.852	30.75	7.823	7.23	1.227	3.28	14.934	13.84	51.954	42.14	12.88	15.99	2.276	1.545	47.74	39.70
	H^2	0.994	0.997	0.999	0.999	0.972	0.990	0.931	0.86	0.627	0.93	0.958	0.977	0.999	0.999	0.999	0.998	0.882	0.681	0.999	0.999
	GA	5.456	3.252	45.381	34.61	1.290	1.501	5.373	4.52	1.811	5.80	0.668	0.661	84.638	95.23	16.19	20.44	0.116	0.075	13.03	13.75
	GAM %	6.09	3.78	64.62	41.16	50.50	63.22	15.71	13.9	2.00	6.45	30.00	28.19	106.60	86.81	26.51	32.92	3.98	2.47	98.31	80.00
Cross-6	PCV %	4.687	2.784	23.02	20.49	36.111	38.38	7.696	7.92	2.300	3.99	13.244	9.49	24.35	27.81	9.948	9.936	8.013	6.04	28.45	24.66
	GCV%	4.686	2.782	23	20.48	35.78	38.24	7.34	7.83	2.15	3.96	12.95	9.46	24.34	27.80	9.93	9.933	7.210	6.02	28.40	24.60
	H^2	99.93	99.80	99.81	99.93	98.24	99.24	91.113	97.76	87.69	98.2	95.71	99.11	99.99	99.99	99.79	99.94	86.96	99.39	99.65	99.51
	GA	8.345	4.771	29.730	30.09	1.596	1.646	4.883	5.012	3.702	7.10	0.597	0.460	25.49	38.95	12.47	12.62	0.497	0.48	6.358	7.229
	GAM %	9.65	5.724	47.35	42.18	73.14	78.47	14.61	15.95	4.17	8.08	26.09	19.39	50.14	57.28	20.45	20.45	13.34	12.36	58.40	50.55

TABLE- 8. Estimates of genetic parameters of six crosses for twelve characters under infected field and greenhouse condition

	Genetic Parameter	PRE_{DOFF} % FI	GHI	$POST_{DOFF}$ % FI	GHI	DI% FI	GHI	PH FI	GHI	PB FI	GHI	DF FI	GHI	DM FI	GHI	CL FI	GHI	CP FI	GHI	SC FI	GHI	SW FI	GHI	SY FI	GHI
Cross-I	PCV%	50.8	70.0	46.56	40.5	50.6	34.9	7.53	3.75	17.85	26.0	9.12	3.96	2.1	2.40	4.35	8.97	19.9	19.7	8.33	10.3	4.79	12.4	15.48	11.6
	GCV%	50.6	70.0	46.53	40.5	50.6	34.9	4.74	3.67	17.60	25.7	8.66	2.25	1.9	2.16	3.93	8.91	19.9	19.5	8.31	10.3	4.73	12.4	15.26	10.1
	H^2	99.9	99.9	99.81	99.9	99.9	99.9	98.2	95.6	97.23	97.4	90.3	32.2	80.0	80.7	82.0	98.7	99.8	99.8	99.5	99.9	97.5	98.5	97.12	76.1
	GA	22.4	35.4	23.75	26.1	40.4	3.85	11.3	4.47	0.67	1.24	6.06	0.95	3.2	3.68	0.13	0.36	19.8	13.6	10.1	11.2	0.27	0.66	2.34	0.95
	GAM%	103	141	94.20	82.5	103	7.18	15.2	7.30	33.77	51.5	16.7	2.63	3.5	3.94	5.64	18.2	40.6	39.7	16.9	21.0	9.40	25.2	30.70	20.4
Cross-II	PCV%	40.0	47.7	17.91	19.9	44.94	32.6	23.9	24.1	18.15	68.2	11.40	60.1	4.04	58.0	6.13	57.3	46.18	73.8	12.1	57.5	8.64	58.2	40.00	65.6
	GCV%	40.0	47.6	17.90	19.7	44.94	32.3	23.9	23.8	18.12	67.0	11.10	58.1	3.88	56.0	6.03	56.3	46.18	71.8	12.1	56.5	8.61	56.2	39.91	65.6
	H^2	99.9	99.9	99.92	9.99	99.94	99.9	99.9	99.9	99.65	99.6	94.75	99.7	92.2	99.9	96.74	99.9	99.90	99.9	99.	99.9	99.53	99.9	99.50	99.8
	GA	24.2	39.6	7.27	10.8	41.26	40.0	38.9	31.2	0.88	3.20	7.83	35.2	7.00	85.1	0.25	1.8	6.72	82.4	13.6	49.4	0.519	2.78	6.63	7.3
	GAM%	81.9	97.8	36.49	40.9	92.58	67.1	48.8	49.2	36.72	136	22.20	119	7.59	179	11.92	115	9.29	147	24.6	1116	17.61	115	81.36	133
Cross-III	PCV %	90.4	94.4	57.82	68.7	62.12	55.0	20.0	33.4	26.86	19.9	12.06	5.14	2.08	3.80	4.14	9.27	37.92	58.4	4.26	9.23	11.22	20.9	31.60	40.6
	GCV%	90.4	92.4	57.77	66.7	62.12	52.0	20.0	30.3	26.74	19.8	11.72	4.95	1.79	3.65	3.80	9.14	37.91	58.4	4.22	9.22	11.20	20.9	31.55	40.3
	H^2	99.9	99.9	99.8	99.9	99.9	99.9	99.8	99.9	99.11	99.2	94.4	92.7	73.6	92.6	84.1	97.3	99.9	99.9	98.0	99.9	99.6	99.8	99.6	98.7
	GA	35.04	45.0	17.35	31.4	36.56	49.0	30.8	37.2	0.97	0.79	8.13	3.42	2.87	0.79	0.11	0.37	56.86	73.5	5.34	10.5	0.75	1.27	7.87	6.58
	GAM %	186.3	190	117.7	138	126.6	107	40.7	64.1	52.88	40.3	23.63	9.88	3.13	0.85	4.73	18.3	78.11	120	8.51	18.8	22.65	42.1	64.25	82.0
Cross-IV	PCV %	20.0	21.5	50.48	49.1	39.59	27.4	18.75	18.9	41.67	37.2	4.12	9.2	1.31	3.5	7.96	8.1	24.6	21.1	11.2	9.2	3.03	13.0	25.14	25.7
	GCV%	19.96	19.5	50.47	47.1	39.58	25.4	18.73	18.8	41.38	37.1	3.42	8.9	1.05	3.4	7.37	6.9	24.58	19.1	11.2	8.2	2.93	12.9	24.66	23.2
	H^2	99.9	99.8	99.9	99.9	99.9	99.9	99.8	99.1	98.6	99.5	68.9	92.7	64.1	92.3	85.8	72.7	99.9	99.6	99.9	99.3	93.7	99.4	96.2	96.4
	GA	14.94	18.1	26.39	28.6	39.32	34.7	27.06	19.5	1.59	2.39	2.10	6.9	1.63	6.52	0.25	0.19	21.48	12.4	11.7	7.6	0.16	0.67	2.62	1.86
	GAM %	40.71	248	103.98	102	81.52	190	38.20	260	84.32	132	5.89	56.4	1.73	146	13.28	87.8	50.14	256	23.0	59.5	5.56	387	49.08	213
Cross-V	PCV%	110.5	117	43.59	34.9	75.05	51.7	18.03	30.4	21.04	19.8	9.25	12.6	3.11	1.33	10.88	57.7	50.72	72.5	14.5	58.3	2.17	55.9	47.09	67.6
	GCV%	110.5	115	43.57	33.8	75.04	51.7	18.01	30.4	21.03	19.4	9.14	12.1	2.95	0.79	10.58	57.5	50.69	72.5	9.50	57.3	2.04	55.9	47.02	67.6
	H^2	99.9	99.9	99.9	99.9	99.9	99.9	99.8	99.9	99.8	96.4	98.4	92.2	90.6	35.5	93.7	99.3	99.9	99.9	42.3	99.9	88.4	99.9	99.9	99.8
	GA	43.37	61.6	13.74	15.3	45.82	50.3	26.61	39.2	0.92	1.15	6.54	10.2	5.32	4.21	0.46	1.97	85.84	96.2	7.78	53.3	0.08	2.65	11.80	8.49
	GAM %	227.6	237	89.72	69.8	154.5	106	36.73	62.7	42.16	41.1	18.9	27.4	5.79	4.59	20.70	118	104.5	149	12.5	120	2.67	114	95.81	105
Cross-VI	PCV %	28.4	36.5	19.40	28.3	13.66	25.1	19.17	28.5	56.68	29.9	8.79	10.5	3.49	1.01	6.45	58.0	46.14	70.0	8.01	58.3	6.16	56.5	34.41	70.6
	GCV%	28.4	36.5	19.39	28.3	13.64	25.1	19.13	28.5	65.60	29.7	8.42	10.3	3.37	0.67	5.84	57.9	46.13	69.9	7.98	58.3	6.18	56.5	34.30	70.5
	H^2	99.9	99.	98.96	99.9	99.98	99.9	99.86	99.9	99.70	99.1	91.76	97.9	93.1	44.0	82.25	99.7	99.96	99.9	99.9	99.9	91.65	99.9	99.34	99.8
	GA	17.9	29.4	10.09	17.9	14.51	34.0	26.84	33.5	1.99	1.19	5.57	7.51	6.01	0.82	2.49	1.9	42.39	45.9	9.99	53.1	0.44	3.4	5.46	8.58
	GAM %	58.0	75.2	39.91	57.7	28.09	51.2	39.09	56.3	115.0	60.2	16.57	20.8	6.69	0.92	108.2	117	94.07	144	16.4	120	11.73	116	69.83	143

found for CP and SC. High GCV and PCV were recorded for PB and PH. High heritability coupled with high GA was recorded for DF and PH for cross combination-IV. Under FC condition, for all the six cross combinations high GCV and PCV coupled with high heritability and GA was estimated for CP and PH. For cross combination-I, high GCV and PCV were estimated for PRE_{DOFF}% and $POST_{DOFF}$%. High heritability with high GA was recorded for $POST_{DOFF}$% and DI%. For cross combinations-II, IV and V, high GCV and PCV were estimated for CP and DI%. High heritability with high GA was recorded for DI%. High GCV and PCV was recorded for PRE_{DOFF}% and DI%. High heritability with high GA was recorded for CP and DI% for cross combination-III. In cross combination-VI, high GCV and PCV were recorded for PB and CP. High heritability coupled with high GA was recorded for CP and PH. For cross combination-I, III and V high GCV, PCV, heritability and GA were found for PRE_{DOFF}% and $POST_{DOFF}$%. High GCV and PCV with high heritability and GA was recorded for CP and SC for cross combination-II. High GCV and PCV were recorded for PB, and $POST_{DOFF}$%. High heritability coupled with high GA were recorded for PRE_{DOFF}% and DI% for cross combination-IV. Similarly, in cross combination VI, all the estimates of genetic parameters were high for SC and CP.

Estimates of Generation Mean Analysis for six crosses under both Field and Greenhouse conditions

To understand the nature and magnitude of gene effects involved in the inheritance of root rot reaction, yield and yield components in sesame and also to provide a basis for an evaluation of selection methods for the improvement of population under both infected and normal condition, the generation mean analysis was carried out by utilizing the six cross combinations namely, Uma × Tillotama, Rama × VRI-1, Tillotama × Gujarat Til-2, Rama × Savitri, Uma × NIC-8316 and TKG-22 × OSC-593. The five generations namely, P_1, P_2, F_1, F_2 and F_3 generations of the crosses were studied for disease, yield and yield components. The estimates of gene effects under both greenhouse and field condition for the all six cross combinations are given in Table 9-14.

Estimates of Genetic Components for disease reaction under both Field and Greenhouse conditions:

From the study, all types of gene effects were found to be significant ($P<0.05$) for root rot resistance for PRE_{DOFF}%, $POST_{DOFF}$% and DI%**.** For the trait PRE_{DOFF}%, all the crosses showed significant additive, dominance, and additive × additive and dominance × dominance type of non-allelic interaction. Complementary type of epistasis was found in most of the crosses except few like, cross-I and III during GHI condition, cross-IV and V in FI condition which showed duplicate type of epistasis. For the trait $POST_{DOFF}$% and DI% the dominance × dominance, additive × additive and the additive gene interaction were found to play an important role. Complementary type of epistasis was found in all the crosses except cross-I and cross-VI for $POST_{DOFF}$% and also for DI% for all the crosses except cross-I under GHI condition. The result suggested that both dominant and additive gene action were involved in root rot resistance under both greenhouse and field conditions. The additive gene effects (d) were positive and highly significant for root rot resistance for PRE_{DOFF}%, $POST_{DOFF}$% and DI% for cross-I under both conditions. Meanwhile negative and significant values were detected for root rot resistance for PRE_{DOFF}%, $POST_{DOFF}$% and DI% for cross-II, III and V. Cross-VI showed negative and significant values for additive gene effects for PRE_{DOFF}% and $POST_{DOFF}$% while positive and significant value for DI%. The results indicated that selection for root rot for resistance for PRE_{DOFF}%, $POST_{DOFF}$% and DI% are important in early generations. The negative and significant values mean that the genotypes that were used in the respective crosses have decreasing alleles for root rot resistance and selection to improve it could be effective. Use of the recurrent selection methods can facilitate the accumulation of resistance genes to develop germplasm with multi-genic resistance that could be effective and durable over time (Badu-Apraku *et al*. 2012). Cross-IV showed positive and high significant additive gene effects for $POST_{DOFF}$% under both conditions and negative significant additive effect for DI% under both FI and GHI conditions. With regard to dominance gene effects negative values were observed for PRE_{DOFF}%,

TABLE 9. Estimates of gene effects for disease and yield related traits of Cross-I under infected and control conditions in ûeld and greenhouse

Population	Gene effects	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	m	30.88**	34.18**	55.43**	-	68.67**	1.96**	34.00**	91.00**	2.20**	53.63**	59.75**	2.70**	6.86**
	d	1.10**	2.18**	1.59**	-	-2.91**	-0.14**	-1.5**	-1.00**	-0.02	-9.72**	-3.81**	-0.013	-1.03**
FI	h	-10.1**	-14.0**	-11.9**	-	-26.4**	-0.66**	0**	-1.11**	-0.51**	6.18**	-7.06**	0.01**	1.20**
	i	-24.2**	-28.1**	-40.6**	-	-17.3**	0.14**	5.50**	2.89**	-0.37**	-8.24**	16.1**	0.07**	-0.37**
	l	-6.00**	0.19	-11.2**	-	53.34**	-0.80**	0	-4.44**	1.07**	-3.20**	35.49**	0.91**	6.70**
	m	-	-	-	86.35**	80.21**	2.08**	31.00**	89.00**	2.38**	71.82**	62.98**	2.83**	11.71**
	d	-	-	-	0.10**	-1.51**	0.07**	-3.0**	0.5	-0.14	-9.75*	-3.89**	0.04	-0.96**
FC	h	-	-	-	-1.19**	7.18**	0.05**	-2.00**	-2.88**	-0.05**	-2.87**	6.54**	0.26**	0.44**
	i	-	-	-	-1.37**	12.46**	0.24**	4.00**	0.28**	-0.09**	-18.0**	-3.61**	0.31**	-2.69**
	l	-	-	-	11.07**	-14.9**	-0.08**	8.00	-0.88**	0.35**	18.05**	7.31**	0.27**	7.42**
	m	34.32**	41.86**	64.32**	-	59.94**	2.15**	35.67**	92.00**	2.16**	38.69**	54.44**	2.70**	4.33**
	d	6.59**	4.97**	10.92**	-	1.64**	0.75**	-0.33**	-2.16**	-0.008	1.48**	0.02	0.40**	0.2
GHI	h	-2.80**	-13.9**	-12.8**	-	0.45**	-1.2**	2.0**	-2.66**	-0.02**	9.09**	4.57**	-0.06**	0.92**
	i	-36.0**	-28.7**	-42.1**	-	4.13**	0.56**	3.33**	0.17**	-0.26**	-5.47**	-8.73**	-0.38**	0.07**
	l	27.61**	-4.68**	25.54**	-	-2.27	0.21**	-2.66**	5.33	-0.47**	-4.73**	19.13**	0.37**	2.64**
	m	-	-	-	88.17**	63.90**	202**	33.33**	91.33**	2.38**	47.85**	59.64**	2.74**	6.99**
	d	-	-	-	0.18	0.07	-0.008	-1.16	-0.66	0.08**	0.02	1.53**	0.21**	0.36**
GHC	h	-	-	-	1.81**	0.03**	-0.02**	0.22**	0.22**	0.27**	3.90**	3.71**	0.10**	0.60**
	i	-	-	-	6.91**	3.86**	0.00**	3.06**	2.89**	-0.24**	-8.19**	-8.53**	-0.05**	-0.29**
	l	-	-	-	-3.18**	-0.29	-0.11	0.88	-4.44**	-0.29**	0.30	15.55**	0.27**	2.91**

*P<0.05, **P<0.01.

Table 10. Estimates of gene effects for disease and yield related traits of Cross-II under infected and control conditions in ûeld and greenhouse

Population	Gene effects	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	m	25.61**	21.13**	41.62**	-	59.67**	2.23**	32.33**	89.33**	2.14**	92.89**	61.99**	3.10**	9.65**
	d	-12.5**	-3.75**	-27.8**	-	-5.80**	0.22**	-1.5**	-0.66	-0.13**	7.48**	2.09**	0.25**	2.34**
FI	h	-1.20**	0.90**	4.38**	-	26.31**	-0.23**	-1.77**	-2.44**	0.02**	3.35**	-4.98**	-0.15**	0.41**
	i	15.32**	-4.26**	8.13**	-	20.44**	0.69**	5.39**	4.22**	-0.15**	-62.2**	-10.0**	-0.40**	-5.46**
	l	-15.6**	3.84**	2.16**	-	97.10**	-0.89**	3.55**	6.22**	0.08	29.52**	-21.7**	-0.08	4.57**
	m	-	-	-	81.21**	70.70**	2.46**	31.33**	87.33**	2.31**	121.20**	64.04**	3.26**	17.00**
	d	-	-	-	0.25**	-9.48**	0.50**	-6.0**	-4.0**	-0.11**	2.24**	2.13**	0.13**	1.79**
FC	h	-	-	-	3.44**	21.09**	0.11**	0.66**	0.22**	-0.03**	0.65**	-5.52**	-0.01**	-0.22**
	i	-	-	-	2.73**	14.76**	0.74**	11.67**	4.56**	-0.34**	-62.44**	-12.16**	-0.35**	-8.71**
	l	-	-	-	6.72**	112.53**	-0.81**	-2.66**	0.88	0.22**	15.2**	-19.55**	-0.11**	1.61**
	m	28.12**	29.55**	50.79**	-	49.63**	2.51**	34.00**	90.67**	2.06**	82.68**	56.73**	3.11**	7.48**
	d	-17.1**	-4.33**	-23.3**	-	-2.88**	2.21**	22.66**	49.00	0.91**	13.08**	25.01**	1.37**	7.49**
GHI	h	3.6**	0.88**	4.46**	-	23.98**	0.19**	-0.22**	0.66**	-0.21**	-0.46**	-5.2**	0.11**	0.36**
	i	27.48**	-7.48**	19.29**	-	3.79**	0.05**	-12.5**	-43.3**	-1.30**	-73.5**	-28.9**	-1.79**	-6.38**
	l	13.65**	1.09**	11.04**	-	97.82**	-0.98**	4.44**	8.00**	0.15**	14.77**	-21.65**	0.008	3.63**
	m	-	-	-	83.48**	54.64**	2.39**	32.67	89.67**	2.30**	94.80**	51.97**	3.21**	11.77**
	d	-	-	-	-0.18**	-15.66**	0.98**	-1.5**	-0.66	-0.08**	-0.52**	7.20**	0.15**	1.05**
GHC	h	-	-	-	-0.30**	21.84**	-0.12**	2.00**	1.33**	0.01**	-3.27**	1.6**	0.004**	-0.42**
	i	-	-	-	2.38**	17.39**	0.82**	14.17**	7.67**	-0.43**	-65.83**	-2.90**	-0.36**	-7.17**
	l	-	-	-	1.75**	101.08**	-1.07**	-2.66**	3.33**	0.26**	22.64**	7.89**	**-0.24****	4.33**

*P<0.05, **P<0.01.

TABLE 11. Estimates of gene effects for disease and yield related traits of Cross-III under infected and control conditions in ûeld and greenhouse

Population	Gene effects	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	m	10.08**	10.07**	19.43**		61.58**	1.74**	32.00**	91.00	2.25**	88.88**	62.82**	3.50**	14.96**
	d	-19.92**	-9.48**	-21.67**	-	3.32**	0.15**	3.16**	0.5	0.09**	7.46**	-0.61	-0.34**	-0.56**
FI	h	2.61**	1.28**	6.40**	-	21.55**	-0.62**	0.44**	-0.88**	-0.06**	6.49**	2.43**	-0.53**	-0.54**
	i	16.11**	9.04**	15.22**	-	0.37**	0.54**	6.28**	2.94**	-0.18**	49.18**	-3.99**	-0.03**	-7.54**
	l	16.48**	7.68**	26.46**	-	104.81**	-1.31**	1.77**	-3.55**	0.80**	28.04**	11.43**	-1.60**	1.37**
	m	-	-	-	86.97**	63.87**	2.20**	30.00	88.33**	2.40**	118.7**	64.68**	3.65**	3.51**
	d	-	-	-	-0.82**	1.45**	-0.01**	4**	0.16	0.19**	4.02**	1.65**	-0.38**	-0.49**
FC	h	-	-	-	1.61**	28.28**	0.12**	-2.88**	-3.33**	-0.11**	-4.27**	1.20**	-0.66**	-0.6**
	i	-	-	-	1.44**	3.97**	0.33**	4.11**	-1.50**	-0.30**	-59.3**	-7.25**	-0.23**	-0.47**
	l	-	-	-	5.82**	125.4**	-0.48**	4.44	2.66	0.82**	15.64**	13.36**	-1.39**	-1.44**
	m	19.12**	16.81**	36.07**		42.28**	2.18**	34.33**	92.00**	2.15**	80.36**	58.76**	3.41**	10.05**
	d	-29.86**	-18.09**	-30.93**	-	-3.34**	0.01	2.16**	4.66**	-0.05**	3.20**	-2.68**	-0.70**	-0.08
GHI	h	-0.04**	-0.64**	6.54**	-	27.16**	-0.86**	1.11**	0.88**	-0.1**	10.35**	0.72**	-0.60**	0.06**
	i	9.74**	14.82**	15.11**	-	6.36**	-0.15**	2.28**	-2.89**	-0.46**	-65.06**	-9.23**	-0.62**	-6.31**
	l	3.92**	0.49	28.30**	-	119.52**	-1.82**	-0.88	12.44**	0.45**	50.68**	6.78**	-1.47**	3.10**
	m	-	-	-	89.78**	49.94**	2.09**	31.67**	90.00**	2.35**	93.64**	62.50**	20.19**	14.97**
	d	-	-	-	-0.01	-1.57**	0.008	2**	1.83**	-0.14**	-2.24**	-3.97**	-0.62**	-1.6**
GHC	h	-	-	-	-2.91**	25.15**	-0.73**	0**	-1.33**	-0.14**	9.67**	1.15**	1.17**	-0.81**
	i	-	-	-	1.03**	2.97**	0.27**	2.67**	-1.50**	-0.78**	-56.7**	-8.33**	-9.16**	-7.34**
	l	-	-	-	3.71**	115.3**	-2.83**	5.3**	10.66**	1.35**	30.10**	9.31**	2.48**	1.28**

*P<0.05, **P<0.01.

TABLE 12. Estimates of gene effects for disease and yield related traits of Cross-IV under infected and control conditions in ûeld and greenhouse

Population	Gene effects	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	m	39.52**	36.65**	61.82**	-	56.78**	1.71**	35.67**	93.67**	1.78**	41.07**	46.44**	2.83**	4.40**
	d	-4.42**	1.67**	-8.08**	-	4.98**	1.08**	1.66**	1.5**	-0.14**	6.99**	-4.65**	0.04	1.17**
FI	h	-2.44**	-8.55**	-2.67**	-	15.07**	-0.39**	2.22**	-0.66**	-0.22**	12.33**	2.92**	0.14**	1.52**
	i	-16.26**	-25.1**	-34.6**	-	15.91**	-0.08**	2.22**	-0.50**	-0.06**	-10.0**	8.52**	0.26**	2.24**
	l	20.04**	-15.34**	-0.71**	-	61.13**	0.94**	-1.77	2.66**	0.72**	47.15**	8.86**	-0.22**	1.68**
	m	-	-	-	78.64**	68.09**	2.03	32.67**	91.67**	2.00**	68.52**	48.65**	2.97**	8.63**
	d	-	-	-	-2.75**	6.85**	1.11**	2.5**	-0.5	-0.14**	6.57**	-5.99**	0.03	0.73**
FC	h	-	-	-	0.55**	14.25**	-0.09**	0.44**	0.22**	-0.3**	5.11**	3.32**	0.10**	0.64**
	i	-	-	-	6.45**	9.96**	0.10**	-0.72**	-5.28**	-0.17**	-10.0**	10.22**	0.11**	0.57**
	l	-	-	-	8.97**	63.10**	0.06**	7.11**	6.22**	0.56**	6.64**	2.70**	-0.16**	3.92**
	m	42.80**	41.82**	77.51**	-	40.15**	2.20**	38.00	96.00**	1.53**	33.45**	41.67**	2.80**	3.52**
	d	0.45**	2.64**	-0.57**	-	5.53**	-0.07**	4.66**	4	0.08**	0.1	1.14**	0.37**	-0.01**
GHI	h	10.63**	-7.31**	0.03**	-	5.16**	0.22**	1.11**	-1.33**	-0.07**	3.66**	3.20**	0.1**	1.70**
	i	-10.43**	-25.9**	-32.2**	-	6.07**	2.15**	2.11**	-5.33**	-0.24**	-10.8**	6.20**	-0.22**	-0.26**
	l	50.05**	-18.3**	10.43**	-	55.15**	0.8**	4.44**	10.66**	1.34**	21.30**	10.48**	-0.61**	5.02**
	m	-	-	-	78.64**	68.09**	2.03**	32.67**	91.67**	2.00**	68.52**	48.65**	2.97**	8.63**
	d	-	-	-	-2.75**	6.85**	1.11**	2.5**	-0.5**	-0.14	6.57**	-5.99**	0.03**	0.73**
GHC	h	-	-	-	0.55**	14.25**	-0.09**	0.44**	0.22**	-0.3**	5.11**	3.32**	0.10**	0.64**
	i	-	-	-	6.45**	9.96**	0.10**	-0.72**	-5.28**	-0.17**	-10.0**	10.22**	0.11**	0.57**
	l	-	-	-	8.97**	63.10**	0.06**	7.11**	6.22**	0.56**	6.64**	2.70**	-0.16**	3.92**

*P<0.05, **P<0.01.

Table 13. Estimates of gene effects for disease and yield related traits of Cross-V under infected and control conditions in ûeld and greenhouse

Population	Gene effects	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	m	9.09**	10.27**	17.56**	-	58.90**	1.89**	33.33**	90.00**	2.35**	108.87**	66.26**	2.97**	16.22**
	d	-22.70**	-5.61**	-24.81**	-	-5.25**	-0.05**	-1.33**	-2.33**	0.27**	-5.16**	-2.31	-0.06**	0.54
FI	h	0.22**	3.06**	5.04**	-	17.14**	0.66**	0**	-2.66**	0.02**	-5.86**	0.58**	-0.13**	-0.06**
	i	25.03**	9.57**	24.67**	-	13.40**	-0.26**	6.33**	1.67**	-0.19**	-84.77**	-13.30**	-0.03**	-11.04**
	l	-0.09	10.32**	18.31**	-	66.11**	3.04**	-5.33**	5.33**	-0.27**	38.95**	7.50	0.09	3.09**
	m	-	-	-	84.55**	67.88**	2.11**	31.00	86.67**	2.56**	140.81**	68.70**	3.00**	21.55**
	d	-	-	-	1.63**	-11.27**	0.35**	-0.83**	-1.00	0.31**	-9.64**	2.60**	0.02	-0.04
FC	h	-	-	-	0.6**	17.74**	6.78**	-0.22**	-0.88**	-0.12**	-1.18**	2.11**	0.02**	-0.02**
	i	-	-	-	1.08**	17.74**	-0.82**	4.28**	4.44**	-0.43**	-87.42**	-16.97**	0.10**	-13.29**
	l	-	-	-	5.65**	72.86**	4.36**	-0.88	1.77**	-0.4**	22.68**	3.02**	-0.008	5.81**
	m	12.00**	15.18**	29.22**	-	43.89**	2.22**	35.67**	91.67**	2.31**	96.91**	60.98**	2.89**	11.94**
	d	-33.13**	-4.58**	-21.37**	-	-3.57**	0.39**	-4.66**	0.83**	0.89**	14.48**	24.18**	1.43**	2.40**
GHI	h	1.03**	5.71**	9.49**	-	29.85**	0.30**	1.55**	1.11**	-0.24**	1.33**	-6.61**	-0.10**	-1.72**
	i	34.20**	11.21**	33.77**	-	10.24**	0.10**	7.56**	-0.39**	-1.28**	-83.45**	-33.70**	-1.55**	-10.34**
	l	2.64**	19.92**	36.27**	-	117.16**	3.60**	-4.44	4.44**	-1.01**	6.78**	-25.61**	0.16**	-0.26
	m	-	-	-	87.92**	48.69**	2.14	32.67**	89.00	2.53**	108.75**	65.84**	2.96**	17.68**
	d	-	-	-	1.64**	-12.13**	-0.67**	-1.83**	1.00	0.17**	3.36**	2.19**	0.05	1.11**
GHC	h	-	-	-	-1.9**	29.09**	0.76**	-0.88**	-1.55**	-0.05**	-1.82**	2.91**	-0.05**	-0.11**
	i	-	-	-	3.93**	15.31**	0.62**	3.61**	-0.89**	-0.47**	-77.01**	-12.96**	-0.12**	-11.97**
	l	-	-	-	-2.66**	121.64**	1.73**	1.77	9.77**	-0.73**	7.19**	5.14**	-0.04	1.66**

*P<0.05, **P<0.01.

Table 14. Estimates of gene effects for disease and yield related traits of Cross-VI under infected and control conditions in ûeld and greenhouse

Population	Gene effects	PRE_{DOFF}%	$POST_{DOFF}$%	DI%	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
	m	30.55**	26.25**	45.37**	-	49.91*	2.39**	32.67**	88.33**	2.23**	55.00*	62.38**	3.96**	9.41
	D	-12.46**	-5.14**	2.59**	-	-4.62**	0.04**	-1.66**	0.66**	-0.06	-2.07**	2.64**	-0.01	0.02**
FI	H	-2.23**	-4.58**	3.97**	-	-13.48**	-1.14**	-2.22**	-2.88**	0.08**	4.22**	2.78**	-0.04**	-1.04**
	I	-2.90**	3.17**	12.47**	-	-10.06**	0.87**	3.78**	3.78**	-0.21**	-40.52**	-7.54**	-0.37**	-6.12**
	L	7.90**	-18.01	11.57**	-	128.33**	-7.26**	-3.55	-0.88**	1.04**	42.51**	10.99**	-0.45**	4.30**
	M	-	-	-	81.46**	61.24**	2.66**	29.67**	85.33**	2.50**	82.83**	64.82**	4.09**	16.84**
	D	-	-	-	2.17**	-6.41	-0.40**	-1.33**	-0.16	-0.10**	-0.92**	2.44**	-0.16**	0.42**
FC	H	-	-	-	-4.65**	-18.79**	-0.92**	0.66**	-2.44**	0.15**	1.47**	2.82**	0.22**	-0.42**
	I	-	-	-	-3.40**	-10.12**	0.50**	4.67**	4.06**	-0.22**	-32.62**	-8.66**	-0.06**	-6.92**
	L	-	-	-	16.16**	144.22**	-4.8**	-2.66**	0.88**	0.009**	9.80	8.53**	-0.77**	4.61**
	M	37.60**	29.91**	49.87**	-	39.75**	2.61**	34.67**	89.67**	2.22**	46.17*	58.13**	3.87**	8.76**
	D	-20.11**	-9.48**	3.50**	-	-13.24**	0.18**	-4	-0.5**	0.81	8.35**	21.37	1.63**	1.50**
GI	H	1.93**	-4.59**	11.53**	-	-16.19**	-0.66**	0**	-1.55**	-0.18**	0.52**	2.61**	-0.18**	-1.21**
	I	1.14**	9.12**	27.56**	-	-1.48**	-0.18**	4.67**	-0.06**	-1.49**	-40.83**	-38.16**	-2.30**	-8.54**
	L	8.25**	-19.39**	44.90**	-	97.84	-4.08**	-1.9**	-0.88	-0.04**	13.07**	10.82**	-0.15**	2.72**
	M	-	-	-	83.76**	45.82**	2.54**	31.67**	87.67**	2.45**	58.86**	62.74**	3.96**	12.60**
	D	-	-	-	3.34	-6.93	-0.52	-1.33**	-0.5	-0.16**	-1.46	-4.92**	-0.07**	-0.40
GHC	H	-	-	-	-4.20**	-14.41**	-0.83**	-0.22**	-1.11**	0.004**	-1.14**	1.28**	0.17**	0.23**
	I	-	-	-	2.44**	2.02**	0.70**	3.44**	2.72**	-0.54**	-24.63**	-9.98**	-0.33**	-6.11**
	L	-	-	-	6.76**	86.12	-4.68	4.44	0.88**	0.33**	10.14**	15.15**	-0.46**	4.71**

*P<0.05, **P<0.01

TABLE 15. Scaling test for twelve characters of six cross combination under infected field and glasshouse condition

	CROSS	SCALE	PRE_{DOFF} %	$POST_{DOFF}$ %	DI%	PH	PB	DF	DM	CL	CP	SC	SW	SY
Field	CROSS I	C	54.49**	56.14**	92.53**	-18.66**	0.52**	-11.00**	-1.33**	-0.34**	19.68**	-3.28**	-1.05**	-5.97**
		D	49.99**	56.29**	84.09**	21.34**	-0.09**	-11.00**	-4.67**	0.47**	17.28**	23.34**	-0.36**	-0.94**
	CROSS II	C	-14.94**	4.67**	-18.44**	-137.9**	-0.47**	-14.33**	-14.67**	0.20**	94.89**	41.91**	0.89**	6.33**
		D	-26.71**	7.55**	-16.81**	-65.16**	-1.15**	-11.67**	-10.00**	0.27**	117.0**	25.59**	0.82**	9.77**
	CROSS III	C	-48.70**	-25.76**	-56.90**	-105.5**	0.23**	-14.33**	-2.33**	-0.46**	70.32**	-3.46**	1.67**	13.71**
		D	-36.34**	-20.00**	-37.06**	-26.94**	-0.75**	-13.00**	-5.00**	0.15**	91.36**	5.11**	0.46**	14.74**
	CROSS IV	C	12.11**	65.58**	70.09**	-92.97**	0.79**	-2.67**	-1.67**	-0.59**	-26.99**	-25.90**	-0.29**	-6.17**
		D	27.42**	54.07**	69.55**	-47.11**	-0.08**	-4.00**	0.33**	-0.05**	8.37**	-19.25**	-0.46**	-4.90**
	CROSS V	C	-49.96**	-29.46**	-67.64**	-92.91**	-2.53**	-7.33**	-8.67**	0.66**	130.58**	19.09**	-0.04**	18.99**
		D	-50.03**	-21.72**	-53.91**	-43.32**	-0.24**	-11.33**	-4.67**	0.45**	159.79**	24.72**	0.03**	21.31**
	CROSS VI	C	-2.1**	11.67**	-36.52**	-108.2**	5.52**	-4.00**	-6.67**	-0.63**	38.53**	4.08**	1.19**	7.94**
		D	3.83**	-1.84**	-27.84**	-11.96**	0.07**	-6.67**	-7.33**	0.16**	70.42**	12.33**	0.85**	11.17**
Greenhouse	CROSS I	C	44.42**	62.09**	58.65**	-5.99**	-1.33**	-4.00**	-5.67**	0.98**	15.68**	-1.67**	0.38**	-2.79**
		D	65.13**	58.58**	77.81**	-7.70**	-1.17**	-6.00**	-1.67**	0.63**	12.12**	12.68**	0.66**	-0.81**
	CROSS II	C	-68.62**	13.87**	-49.62**	-105.4**	0.89**	20.67**	78.67**	2.45**	132.27**	79.45**	3.58**	9.12**
		D	-58.38**	14.69**	-41.34**	-32.04**	0.15**	24.00**	84.67**	2.56**	143.35**	63.21**	3.59**	11.84**
	CROSS III	C	-23.39**	-30.13**	-58.52**	-132.0**	2.13**	-3.67**	-6.67**	0.47**	79.43**	11.69**	2.71**	9.52**
		D	-20.45**	-29.76**	-37.30**	-42.61**	0.76**	-4.33**	2.67**	0.81**	117.44**	16.77**	1.60**	11.84**
	CROSS IV	C	-29.19**	70.27**	54.05**	-67.30**	-5.09**	-8.67**	0.00**	-0.87**	0.45**	-22.89**	1.06**	-4.51**
		D	8.35**	56.52**	61.87**	-25.9**	-4.49**	-5.33**	8.00**	0.14**	16.43**	-15.03**	0.60**	-0.74**
	CROSS V	C	-71.04**	-42.34**	-103.8**	-137.6**	-3.82**	-10.67**	-3.67**	3.58**	160.11**	93.02**	2.94**	20.94**
		D	-69.05**	-27.40**	-76.6**	-49.77**	-1.11**	-14.00**	-0.33**	2.82**	165.20**	73.80**	3.06**	20.74**
	CROSS VI	C	-10.35**	1.16**	-100.0**	-94.88**	4.44**	-9.33**	1.00**	3.02**	68.58**	65.50**	4.74**	14.56**
		D	-4.34**	-13.39**	-66.34**	-21.50**	1.38**	-9.33**	0.33**	2.98**	78.39**	73.62**	4.63**	16.41**

*P<0.05, **P<0.01.

TABLE- 16. Scaling test for ten characters of six cross combination under control field and glasshouse condition

	CROSS	SCALE	GER%	PH	PB	DF	DM	CL	CP	SC	SW	SY
Field	CROSS I	C	-8.33**	-9.99**	-0.39**	-16.00**	0.33**	-0.17**	17.97**	-0.09**	-0.89**	-2.04**
		D	-0.02**	-21.18**	-0.46**	-10.00**	-0.33**	0.09**	31.51**	5.39**	-0.68**	3.52**
	CROSS II	C	-12.18**	-142.05**	-0.67**	-20.67**	-10.00**	0.45**	109.68**	43.87**	0.82**	15.81**
		D	-7.14**	-57.65**	-1.28**	-22.67**	-9.33**	0.62**	121.08**	29.21**	0.73**	17.02**
	CROSS III	C	-8.71**	-133.41**	-0.17**	-12.67**	0.33**	-0.22**	103.03**	1.14**	1.85**	15.83**
		D	-4.34**	-39.30**	-0.53**	-9.33**	2.33**	0.40**	114.76**	11.16**	0.81**	17.70**
	CROSS IV	C	-21.89**	-83.03**	-0.26**	-5.67**	4.33**	-0.23**	13.49**	-23.15**	-0.06**	-5.06**
		D	-15.15**	-35.70**	-0.21**	-0.33**	9.00**	0.19**	18.47**	-21.12**	-0.18**	-2.12**
	CROSS V	C	-7.82**	-108.34**	-2.72**	-7.67**	-10.67**	1.27**	152.15**	30.92**	-0.19**	20.76**
		D	-3.58**	-53.69**	0.55**	-8.33**	-9.33**	0.97**	169.17**	33.19**	-0.20**	25.12**
	CROSS VI	C	-9.36**	-123.99**	3.80**	-6.67**	-9.00**	0.35**	55.44**	8.78**	0.90**	9.23**
		D	2.76**	-15.82**	0.20**	-8.67**	-8.33**	0.42**	62.79**	15.18**	0.32**	16.69**
Greenhouse	CROSS I	C	-10.64**	-7.42**	0.12**	-7.00**	-1.33**	0.77**	16.07**	1.50**	-0.17**	-2.34**
		D	-13.02**	-7.64**	0.04**	-6.33**	-4.67**	0.55**	16.30**	13.17**	0.04**	-0.15**
	CROSS II	C	-6.50**	-135.87**	-0.57**	-25.67**	-20.67**	0.59**	109.02**	-2.09**	0.97**	9.99**
		D	-5.19**	-60.06**	-1.38**	-27.67**	-16.67**	0.79**	126.00**	3.83**	0.79**	13.25**
	CROSS III	C	-5.78**	-121.29**	2.29**	-10.67**	-7.67**	0.21**	83.41**	7.35**	2.37**	13.40**
		D	-3.00**	-34.77**	0.16**	-6.67**	0.33**	1.22**	105.99**	14.34**	1.29**	14.36**
	CROSS IV	C	-12.84**	-58.49**	-2.26**	-10.00**	-4.67**	0.35**	3.72**	-16.41**	0.31**	-4.10**
		D	-12.66**	-34.23**	-1.82**	-6.67**	1.33**	-0.10**	11.86**	-10.77**	0.15**	-0.88**
	CROSS V	C	-5.26**	-152.27**	-2.97**	-9.00**	-8.00**	1.68**	146.82**	20.78**	0.28**	21.88**
		D	-7.21**	-61.03**	-1.67**	-7.67**	-0.67**	1.13**	152.22**	24.64**	0.25**	23.13**
	CROSS VI	C	-11.64**	-90.17**	3.28**	-11.33**	-6.33**	0.75**	39.12**	4.81**	1.12**	7.50**
		D	-6.56**	-25.57**	-0.23**	-8.00**	-5.67**	1.00**	46.72**	16.18**	0.77**	11.03**

*P<0.05, **P<0.01

$POST_{DOFF}$% and DI% for Cross-I and IV under FI condition while positive and non-significant gene effects were observed for cross – II, III, V and VI for DI%. With respect to additive x additive type gene effects, positive and significant effects were observed for PRE_{DOFF}%, $POST_{DOFF}$% and DI% for Cross-III, V, VI and also for cross – II in case of PRE_{DOFF}% and DI%. Negative and significant effects were observed for all three disease related traits in case of cross- I and IV while $POST_{DOFF}$% of cross-II also showed significant negative additive x additive type gene effects. Negative sign of interaction suggest an interaction between increasing and decreasing alleles, thus providing evidence of dispersion of genes in the parents (Mather 1949). Concerning the dominance x dominance gene action, positive and highly significant effects were detected for PRE_{DOFF}%, $POST_{DOFF}$% and DI% for all the six crosses except cross-I where PRE_{DOFF}%, DI% and for cross-VI where $POST_{DOFF}$% showed negative and significant gene effects.

Estimates of Genetic Components for yield and yield components under both Field and Greenhouse conditions:

For Ger%, DF and DM, magnitude of dominance x dominance, additive and additive × additive gene effect was significant and higher. Both duplicate and complementary type of epistasis was recorded in the crosses for Ger% while for DF, duplicate type of epistasis was found in all the crosses except few that showed complementary type of epistasis. Inheritance of this trait in most the crosses for DM was under the control of duplicate type of epistasis except for cross-VI under both GHI and FI condition. Duplicate epistasis for all these traits has also been reported by Pathak and Dixit (1988). In the case of the PH and CP, the dominance variance was greater in magnitude than additive variance in all the crosses. Higher magnitude of significant dominance component suggested that the selection of genotypes with higher number of capsules need to be postponed till later generations when the dominance effect would have diminished. This trait showed complementary type of epistasis in all cases except few crosses like cross-I and cross-V, where duplicate type of epistasis was observed which was earlier reported by Ganesh (1999). For CP duplicate epistasis was major contributing component in most of the crosses except few like cross-IV. The present findings finds support from the earlier report by Sharmila*et al.* (2007). For the trait PB both additive and dominance effects were highly significant in all the crosses with higher magnitude of dominance in all the crosses which suggested its greater role in the expression of this trait. Duplicate type of gene action was observed in all the crosses under both field and greenhouse except cross-V. Duplicate type of epistasis was earlier reported by Kumar *et al.* (1998). For the improvement of the trait such as PB, reciprocal breeding techniques would be more appropriate because of presence of both additive and dominance gene actions. In case of the trait SC dominance and dominance x dominance and additive type of non-allelic gene interaction was found to be highly significant in almost all the crosses. This trait was under the control of duplicate type of epistasis in all cross combinations. For CL, the magnitude of additive effect was higher compared to dominance in most of the crosses indicating its predominant role in the expression of this trait. Selection in early segregating generations would be effective in the case of higher magnitude of additive effects than non-additive ones and for exploiting this trait pedigree selection could be suitable. Complementary type of epistasis was noticed in three cross combination while duplicate type was found in cross combinations-V, VI and IV. Sundari *et al.* (2012) also reported the presence of additive x additive and dominance x dominance epistasis interaction for CL. For the trait SW, the dominance, additive and additive × additive gene effects were found to be highly significant in all the cross combinations. Inheritance of this trait in most the crosses were under the control of duplicate type of epistasis as reported by Pathak and Dixit (1988). Cross combination I and III showed complementary type of epistasis. Dominance × dominane gene effects were highly significant in all the crosses for SY which finds support from the earlier findings of Kumar *et al.* (1998), Sundari *et al.* (2012). Duplicate type of epistasis played significant role in the inheritance of SY in cross combination V, VI, II and III while, complementary type of epistasis was

evident in cross combinations - I and IV. In the present study, it was observed that dominance x dominance gene action was an important component for the expression of the trait SY engendering that conventional selection would not be much effective for of SY. It could be advisable that either postponement of selection in later generations or inter-mating among the selected segregants followed by one or two generations of selfing would be effective to break the undesirable linkage and allow the accumulation of favorable alleles for the improvement of this traits. The scaling test was employed to detect the presence or absence of epistasis precisely, which can either be complimentary or duplicate at the di-genic level. The C and D scaling tests provided a test for type l and i epistasis, respectively. The type of epistasis was determined only when dominance and dominance x dominance effects were significant and when these effects had the same sign the effects were complementary while different signs indicated duplicate effect. It is evident from the Table 15-16 that in general, scales C and D are highly significant for disease, SY and all the other yield and disease components, indicating the predominance of non-allelic interactions for all the characters in all of the crosses. Dominant gene effects were found to be relatively more important, as indicated by the fact that in all crosses under both screening conditions the dominance values were higher than the additive values. Therefore, crossing of desirable segregating lines followed by selection can help to obtain progenies with greater level of resistance then either parent. The present investigation showed that data for the presence of epistasis for both additive × additive and dominance × dominance type interaction were significant in yield and related traits in different crosses. However, the magnitude of the l type of epistasis was greater than that of i type for different traits which implies genetic variation can't be easily exploited with non-directional and unfixable components. In the present study, it could be concluded that dominance gene effects played major role in controlling the genetic variance of trait SY. However, additive gene effects also found to be important for inheritance of some yield related traits such as CL. Presence of epistatic gene interactions in the inheritance of some of studied characters indicated that during breeding for such traits, selection of plants in early generations would not be effective as they would not reproduce progeny with the same magnitude of the trait due to recombination hence postponed selection would be advisable. However, when dominance and epistatic effects are significant recurrent selection for handling these crosses for rapid improvement can be suggested. Identiûcation of linked markers to root rot would be advisable for the selection of rare recombinants that combine the favorable alleles for resistance to root rot. Further research should focus on the characterization of the genes underlying root rot resistance QTLs of different genetic resources and the isolation of the candidate genes for root rot resistance in sesame.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 191-200, 2016

Effect of Integrated Nutrient Management on Productivity and Profitability of Different Potato-based Cropping Sequences Under Lower Gangetic Plains of West Bengal

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Published : 30.10.2017

Abstract

A field experiment was conducted during *rabi* seasons of 2013-14 and 2014-15 at C-unit research farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to evaluate four potato based cropping systems viz. potato-cowpea-rice, potato-greengram-rice, potato-groundnut-rice and potato-sesame-rice under integrated nutrient management (INM). The highest total potato equivalent yield (PEY) (76.59 t ha^{-1} and 79.67 t ha^{-1}) was recorded in potato-cowpea-rice cropping sequence. Among the INM approaches, the highest total PEY (53.16 and 56.22 t ha^{-1}) was recorded under the treatment that received 75% recommended dose of N, P and K through inorganic sources along with FYM @ 10 t ha^{-1} applied to both potato and rice crops and *pre kharif* crop was grown under residual fertility of the previous crop. Among the interaction effects potato-cowpea-rice cropping sequence produced the highest total PEY (81.23 t ha^{-1} and 85.20t ha^{-1}) with the application of 75% recommended dose of N, P and K through inorganic sources in combination with FYM @ 10 t ha^{-1} to potato and rice crops. The lowest total PEY was recorded in potato-sesame-rice sequence with 75% recommended dose of nutrients to potato and rice through inorganic sources (T_2). Integrated use of inorganic fertilizers in combination with organic sources of nutrients increased the gross and net return of the cropping systems as compared to the use of 100% RDF of NPK and 75% RDF of NPK applied through inorganic fertilizers alone. In both the years highest net return was obtained from potato-cowpea-rice cropping sequence.

Introduction

The predominant cropping sequences under irrigated conditions in new alluvial zone of West Bengal are potato based. In West Bengal, potato is a very important crop. Again cropping system involving legumes are the effective options for minimizing the second generation problems and to make a breakthrough in productivity and profitability. The legumes in cropping system can deliver many agronomic and ecological benefits, while maintaining or enhancing the scale of efficiency of production. It has been also found that combined application of organic and inorganic sources of nutrients improved the soil nutrient status and nutrient uptake by the crops in sequences as compared to chemical fertilizers alone. Thus, an attempt was made to assess various potato based cropping systems involving legume and non-legume crops in the summer season and rice, the main crop in *kharif* season under different levels for higher productivity under agro-climatic conditions of alluvial plains of West Bengal. The present experiment was carried out with the objective to study the system productivity and profitability of four dominant potato-based cropping systems under integrated nutrient management practices in West Bengal.

Materials and Methods

The field experiment was conducted during *rabi* seasons of 2013-14 and 2014-15 at C-unit research farm of Bidhan Chandra Krishi Viswavidyalaya,

Kalyani, Nadia, West Bengal, India. The soil was Entisol and sandy loam in texture and slightly alkaline in reaction (pH 7.2) having an organic carbon content of 0.56%, 183.26 Kg available N ha^{-1}, 16.8 kg available P_2O_5 ha^{-1}, 132 kg available K_2O ha^{-1}. The experiment was laid out in a split plot design with three replications. Four different cropping systems, viz. S_1- potato-cowpea-rice, S_2 - potato-greengram-rice, S_3 -potato-groundnut-rice and S_4 - potato-sesame-rice were randomly allotted in four main plots. The five sub-plot treatments were, T_1- 100% RD of NPK, T_2- 75% RD of NPK, T_3- 75% RD of NPK+ FYM @ 10 t ha^{-1} , T_4- 75% RD of NPK+ Neem cake @ 1 t ha^{-1} and T_5- 75% RD of NPK+ Bio-fertilizers (*Azotobacter* and phosphobacteria). Each sub-plot was of 4m × 3m size. The five levels of nutrient management practices were applied to both potato and rice crops. The recommended doses of NPK (kg ha^{1}) were 200:150:150 for potato, 80:40:40 for rice. Cowpea, greengram, groundnut and sesame were grown under residual fertility of the previous crop of potato. The varieties used were Kufri Jyoti, Khitish, Pusa Dofasli, Panna, AK-12-24 and Tillottama for potato, rice, cowpea, greengram, groundnut and sesame, respectively. The system productivity was expressed in terms of potato equivalent yield. The statistical analysis of data for the *rabi* crop i.e. potato and *kharif* crop rice were done adopting split-plot design procedure and for summer crops namely cowpea, greengram, groundnut and sesame only mean data were compared for discussing yield of those crops. Analysis of variance of the data in the experimental design and comparison of means at $p \leq 0.05$ were carried out, using MSTAT-C software.

Results and Discussion

Effect of cropping sequence on tuber yield of potato

Cropping sequences had significant effect on the tuber yield of potato in both the years of investigation (Table 1). The yield response was comparatively higher in the second year. The crops grown in between two potato crops might have attributed higher yield of potato crops in the second or concluding year of investigation. The highest tuber yields of potato (31.16 and 31.82 t ha^{-1} during 2013-14 and 2014-15, respectively) were recorded in potato-cowpea-rice sequence (S_1), which was significantly superior to all other treatments. The higher yield might be ascribed to higher dry matter production in these treatments and translocation and the conversion of photosynthates in to tubers. Legume crops were grown in those sequences after potato. This inclusion of legumes might have attributed to improved soil physico-chemical condition for obtaining higher potato yield. Pal *et al.* (1993) reported that inclusion of one legume crop in any cropping sequence increased potato tuber yield. The lowest tuber yield of potato (27.64 and 28.58 t ha^{-1} in 2013-14 and 2014-15, respectively) was recorded with the treatment where non-legume crop was grown after potato i.e. potato-sesame-rice cropping sequence (S_4).

Effect of nutrient management on tuber yield of potato

Nutrient management practices significantly affected the tuber yield of potato (Table 1). Application of organic sources of nutrients recorded distinct yield advantage over application of inorganic sources of nutrients (100 % or 75 % RDF). The tuber yield of potato obtained (29.95 and 30.43 t ha^{-1} during 2013-14 and 2014-15 respectively) from the treatment 75% recommended dose of NPK and FYM @ 10 t ha^{-1} (T_3) was significantly superior to all other treatments in both years of experiment. This might be attributed to improved soil physical condition and higher availability of macro- and micro- nutrients with the addition of FYM. The result confirm the findings of Mukherjee and Gaur (1985) and Rao *et al.* (1990). The result also indicated a saving of 25% RDF by 10 t FYM. The other treatments which recorded higher yields in diminishing order were T_5 containing 75% recommended dose of NPK fertilizers along with bio-fertilizers, *Azotobacter* and phosphobacteria) (29.48 and 30.23 t ha^{-1} during 2013-14 and 2014-15, respectively) and T_4 containing 75% recommended dose of NPK through inorganic sources along with Neemcake @ 1 t ha^{-1} (29.23 and 29.63 t ha^{-1} during 2013-14 and 2014-15, respectively). Praharaj (2006) also obtained higher potato yield by inoculating potato tubers with *Azotobacter* and Azophos. Mondal *et al.*

TABLE 1. Effect of cropping sequence and nutrient management on the yield (t ha^{-1}) of potato and rice

Treatments	Tuber yield (t ha^{-1})		Mean	Rice yield (t ha^{-1})		
	2013-14	2014-15		2013-14	2014-15	Mean
Cropping sequence						
S_1 (Potato-cowpea-rice)	31.160	31.820	31.490	4.3	4.46	4.3
S_2 (Potato-greengram-rice)	28.300	29.500	28.900	3.68	3.86	3.68
S_3 (Potato-groundnut-rice)	29.680	30.140	29.910	4.02	4.14	4.02
S_4 (Potato-sesame-rice)	27.640	28.580	28.110	3.52	3.64	3.52
S.Em (±)	0.44	0.16		0.01	0.027	0.01
C.D. (P = 0.05)	1.27	0.46		0.03	0.08	0.03
Nutrient management treatments						
T_1 (100% recommended dose N, P_2O_5 and K_2O)	28.800	29.950	29.375	3.58	3.75	3.58
T_2 (75% recommended dose N, P_2O_5 and K_2O)	28.525	29.825	29.175	3.40	3.50	3.40
T_3 (75% recommended dose N, P_2O_5 and K_2O + FYM @ 10 t ha^{-1})	29.950	30.425	30.188	4.45	4.60	4.45
T_4 (75% recommended dose N, P_2O_5 and K_2O + Neemcake @ 1 t ha^{-1})	29.225	29.625	29.425	3.90	4.03	3.90
T_5 (75% recommended dose N, P_2O_5 and K_2O + Bio-fertilizers	29.475	30.225	29.850	4.08	4.25	4.08
S.Em (±)	0.13	0.11		0.02	0.02	0.02
C.D. (P = 0.05)	0.43	0.36		0.06	0.05	0.06

(2005) also reported that application of neem seed powder and neemcake was very effective in increasing tuber yield of potato and production of more 'A' grade (>75g) tubers. Among the inorganic nutrients 100% recommended dose of NPK (T_1) was found to be superior to 75 % of the recommended dose of NPK (T_2) in both the years of experimentation.

Interaction effect of cropping sequence and nutrient management on tuber yield of potato

The data revealed that, all the cropping sequences produced higher tuber yield of potato with the application of 75% recommended dose of NPK inorganic fertilizers along with FYM @ 10 t ha^{-1} (Table 2). In all the nutrient management treatments and cropping sequences where legume crop was grown after potato produced higher tuber yield of potato. The highest tuber yield of potato (31.50 t ha^{-1} and 32.30 t ha^{-1}) was recorded with the application of 75% recommended dose of NPK through inorganic sources along with FYM @ 10 t ha^{-1} (T_3) in potato-cowpea-rice sequence (S_1). Potato grown after legumes (cowpea, groundnut, greengram) produced comparatively more yield and biomass than other non-legume crop in the system. The result was in agreement with the observation of Chettri *et al*., 2004. The lowest tuber yield of potato (26.80 t ha^{-1} and 28.30 t ha^{-1}) was recorded in potato-sesame-rice sequence (S_4) where non-legume crop was grown in sequence and were fertilized with 75% of the recommended dose of inorganic sources of nutrients only.

Effect of cropping sequence on grain yield of rice

The grain yield rice was significantly influenced by different cropping sequences in both the years of experimentation (Table 1). The highest grain yield of rice (4.30 and 4.46 t ha^{-1} during 2013-14 and 2014-15 respectively) was recorded in potato-cowpea-rice sequence (S_1), which was significantly superior to all

TABLE 2. Interaction effect of cropping sequence and nutrient management on the yield (t ha^{-1}) of component crops

Treatment	2013-14			2014-15		
Potato-cowpea-rice (S_1)	Cowpea	Potato	Rice	Cowpea	Potato	Rice
T_1- 100% RD of NPK	6.88	30.90	4.00	6.90	31.60	4.20
T_2- 75% RD of NPK	6.60	30.80	3.80	6.63	31.50	3.90
T_3- 75% RD of NPK+ FYM @ 10 t ha^{-1}	7.83	31.50	4.90	8.03	32.30	5.10
T_4- 75% RD of NPK+ Neem cake @ 1 t ha^{-1}	7.25	31.20	4.30	7.40	31.80	4.40
T_5- 75% RD of NPK+ Bio-fertilizers	7.58	31.40	4.50	7.78	31.90	4.70
Potato-green gram -rice (S_2)	Green gram	Potato	Rice	Green gram	Potato	Rice
T_1- 100% RD of NPK	1.140	27.80	3.40	1.121	29.40	3.60
T_2- 75% RD of NPK	1.074	27.60	3.20	1.086	29.30	3.30
T_3- 75% RD of NPK+ FYM @ 10 t ha^{-1}	1.244	29.40	4.20	1.254	29.70	4.40
T_4- 75% RD of NPK+ Neemcake @ 1 t ha^{-1}	1.150	28.30	3.70	1.164	29.50	3.90
T_5- 75% RD of NPK+ Bio-fertilizers	1.194	28.40	3.90	1.215	29.60	4.10
Potato-groundnut -rice (S_3)	Groundnut	Potato	Rice	Groundnut	Potato	Rice
T_1- 100% RD of NPK	1.79	29.60	3.70	1.95	30.40	3.80
T_2- 75% RD of NPK	1.75	28.90	3.50	1.89	30.20	3.60
T_3- 75% RD of NPK+ FYM @ 10 t ha^{-1}	1.99	30.40	4.60	2.09	30.80	4.70
T_4- 75% RD of NPK+ Neem cake @ 1 t ha^{-1}	1.83	29.70	4.10	1.99	28.60	4.20
T_5- 75% RD of NPK+ Bio-fertilizers	1.92	29.80	4.20	2.04	30.70	4.40
Potato-sesame -rice (S_4)	Sesame	Potato	Rice	Sesame	Potato	Rice
T_1- 100% RD of NPK	1.0	26.90	3.20	1.12	28.40	3.40
T_2- 75% RD of NPK	0.97	26.80	3.10	1.09	28.30	3.20
T_3- 75% RD of NPK+ FYM @ 10 t ha^{-1}	1.13	28.50	4.10	1.23	28.90	4.20
T_4- 75% RD of NPK+ Neem cake @ 1 t ha^{-1}	1.03	27.70	3.50	1.14	28.60	3.60
T_5- 75% RD of NPK+ Bio-fertilizers	1.08	28.30	3.70	1.17	28.70	3.80
	CD (P=0.05) 2013-14			CD (P=0.05) 2014-15		
	Potato-cowpea-green gram-sesame-rice			Potato-cowpea-green gram-sesame-rice		
Interaction	0.09	-	- - 0.08	0.24	-	- - 0.80

other potato based cropping systems studied in this investigation. Rice crop grown after legumes (cowpea, groundnut, greengram) produced comparatively more yield and biomass than other non-legume crop (sesame) in the system. Lowest grain yield of rice (3.52 and 3.65 t ha^{-1} in 2013-14 and 2014-15, respectively) was recorded in potato-sesame-rice cropping sequence (S_4) where non-legume crop was grown before rice.

Effect of nutrient management on grain yield of rice

The grain yield of rice differed significantly due to different nutrient management treatments (Table 1). Significantly highest grain yield of rice (4.45 t ha^{-1} and 4.60 t ha^{-1}) was recorded in the treatment received 75% recommended dose of NPK through inorganic sources in conjunction with FYM @ 10 t ha^{-1} (T_3). In both the years lowest yield of rice was recorded under T_2 (75% RDF applied through the inorganic fertilizers). Application of organic manure/ matter plays a significant role to enhance the productivity of crops. Mondal *et al.* (1988) reported an increase in yield of rice by 12%, 33% and 41% in first, second and third year, respectively over control, through application of FYM @ 15 t ha^{-1}. Even, farm yard manure @ 10 t ha^{-1} when applied to rice yielded higher (34.4 q ha^{-1}). Mondal *et al.* (1990) that reported that the grain yield of rice improved significantly with the application of farmyard manure over the inorganic fertilizer and the grain yield was increased by 24%. Improvement in grain yield and quality of rice by FYM application was also reported by Hemalatha *et al.* (2001).

Interaction effect of cropping sequence and nutrient management on grain yield of rice

The highest grain yield of rice (4.90 t ha^{-1} and 5.10 t ha^{-1}) was obtained with the application of 75% recommended dose of NPK + FYM @ 10 t ha^{-1}(T_3) in potato-cowpea-rice cropping sequence (S_1) (Table 2), closely followed by the yield (4.70 t ha^{-1}) recorded in potato-groundnut-rice cropping sequence (S_3) with the same nutrient management treatment. The lowest grain yield of rice (3.10 t ha^{-1} and 3.20 t ha^{-1}) was recorded in potato-sesame-rice sequence (S_4) having no legume crop in sequence and was fertilized with depleted doses of inorganic sources of nutrient only (T_2).

Effect of treatments on yield of *pre kharif* crops grown under residual fertility

All the *pre kharif* crops grown under residual fertility of 75% recommended dose of N, P and K along with FYM @ 10 t ha^{-1}recorded highest yield (Table 2). The lowest yield was recorded in the treatment T_2 (75% recommended dose of fertilizer through inorganic sources only). The result corroborated with the findings of Dhane *et al.* (1996) and Sanyal *et al.* (1993).The increase in yield of summer crops in sequence under the residual fertility of organic and inorganic sources of nutrients might be due to the fact that organic manure/ matter helped in increasing available nutrients to the crops other than N, P and K under irrigated eco-system. This view was an agreement with the findings of Biswas and Benbi (1989).

Effect of cropping sequence on total potato equivalent yield

Total potato equivalent yield differed significantly with different cropping sequences (Table 3). The highest total potato equivalent yield (76.59 t ha^{-1} and 79.67 t ha^{-1}) was recorded in potato-cowpea-rice cropping sequence (S_1). High yield obtained from all the component crops accounted for the highest potato equivalent yield in this system. Incorporation of legumes had positive influence on soil physical properties which in turn influenced the yield of the potato and rice crop in the sequence. Since the cumulative influence became higher on enrichment of soil fertility, the second year yield was comparatively more in all the sequences. Hence, legumes are preferred in summer season because of their low requirement of fertilizers, water and other inputs and positive role on succeeding crops through enrichment of soil. The lowest total PEY (38.84 and 42.06 t ha^{-1}) was observed in potato-sesame-rice (S_4) cropping sequence.

Effect of nutrient management on total potato equivalent yield

In both the years of experimentation, nutrient management practices significantly influenced the total

TABLE 3. Effect of different cropping sequences and nutrient management on the total potato equivalent yield in system (PEY t ha^{-1} $year^{-1}$)

Treatments	Potato equivalent yield (t ha^{-1} $year^{-1}$)		
	2013-14	2014-15	Mean
Cropping sequence			
S_1 (Potato-cowpea-rice)	76.59	79.67	81.61
S_2 (Potato-greengram-rice)	40.17	43.68	42.95
S_3 (Potato-groundnut-rice)	45.22	48.25	48.03
S_4 (Potato-sesame-rice)	38.84	42.06	40.64
S.Em (±)	1.76	1.65	
C.D. (P = 0.05)	6.08	5.70	
Nutrient management treatments			
T_1 (100% recommended dose N, P_2O_5 and K_2O)	48.60	52.08	51.57
T_2 (75% recommended dose N, P_2O_5 and K_2O)	47.49	50.78	50.36
T_3 (75% recommended dose N, P_2O_5 and K_2O + FYM @ 10 t ha^{-1})	53.16	56.22	56.57
T_4 (75% recommended dose N, P_2O_5 and K_2O + Neemcake @ 1 t ha^{-1})	50.25	53.12	53.17
T_5 (75% recommended dose N, P_2O_5 and K_2O + Bio-fertilizers	51.53	54.89	54.86
S.Em (±)	0.97	0.96	
C.D. (P = 0.05)	2.79	2.76	

PEY (Table 3). The highest total PEY (53.16 and 56.22 t ha^{-1}) was recorded under the treatment that received 75% recommended dose of N, P and K through inorganic sources along with FYM @ 10 t ha^{-1} (T_3). This might be due to significant increase in yield of all component crops in this treatment. Increase in availability and absorption of NPK as a result of combined application of inorganic fertilizers and FYM promoted higher yields in all the component crops in the systems. The lowest total PEY (47.49 and 50.78 t ha^{-1}) was obtained under the treatment that received 75% recommended dose of N, P and K through inorganic sources only (T_2).

Interaction effect of cropping sequence and nutrient management on total potato equivalent yield

In the both years of experiments potato-cowpea-rice cropping sequence produced the highest total PEY (81.23 t ha^{-1} and 85.20t ha^{-1}) with the application of 75% recommended dose of N, P and K through inorganic sources in combination with FYM @ 10 t ha^{-1} to potato and rice (Table 4). The lowest total PEY was recorded in potato-sesame-rice (S_4) sequence with 75% recommended dose of nutrients to potato and rice through inorganic sources (T_2).

Economics

In both the years the highest net return (Rs. 1, 93, 372 and 2, 35, 775) were obtained from potato-cowpea-rice (S_1) sequence (Table 5). This was due to higher potato equivalent yield from cowpea and rice as compared to other crops in other sequences. Higher potato yield in this sequence also attributed to higher potato equivalent yield in this system. Similar results were reported from rice-potato-cowpea sequence by Sharma *et al.* (2004).

Integrated use of inorganic fertilizers in combination with organic sources of nutrients increased the gross and net return of the cropping systems as compared to the use of 100% NPK and 75% NPK applied through inorganic fertilizers alone. The highest gross return was obtained from the treatment receiving 75% recommended dose of N, P and K through inorganic sources along with FYM @ 10 t ha^{-1}. This corroborated with the findings of Jeyabel *et al.* (1999). Potato-cowpea-rice (S_1) sequence computed the highest return per rupee invested (2.60 and 2.85) during both the years of study. Among the nutrient management practices the highest return per rupee invested (1.88 and 2.14) were obtained from T_5 (75% recommended dose of N, P and K through inorganic sources along with Bio-fertilizers, *Azotobacter* and Phosphobacteria). This might be due to lower cost of biofertilizers which in turn reduced the total cost of cultivation of the component crops in different potato based cropping systems.

Conclusion

Based on two years data, it can be concluded that, among the four potato based cropping sequences those are prevalent in West Bengal, potato-cowpea-rice was found to be the best in terms of productivity and profitability. Cowpea was grown as a vegetable crop. Thus it may be concluded that inclusion of legume vegetables in potato based crop sequences with rice can boost the profitability of the system. The highest net return was obtained from potato-cowpea-rice sequence grown with 75% RDF of NPK along with FYM @ 10 t ha^{-1} to potato and rice crops. Cultivation of legumes as summer crop in between potato and rice under residual fertility produced comparatively more yield and biomass than growing other non-legume crops in potato rice system. Hence, farmers should take one legume crop in the summer season to achieve higher production from their cropping system on sustainable basis.

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TABLE 4. Interaction effect of cropping sequence and nutrient management on potato equivalent yield in system (t ha^{-1} $year^{-1}$) in 2006-07 and 2007-08

Nutrient management treatments	Cropping Sequence									
	2013-14					2014-15				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
T_1 (100% recommended dose N, P_2O_5 and K_2O)	73.81	39.02	44.25	37.30	48.60	76.60	42.74	47.66	41.32	52.08
T_2 (75% recommended dose N, P_2O_5 and K_2O)	71.80	38.23	43.0	36.93	47.49	74.22	41.76	46.52	40.61	50.78
T_3 (75% recommended dose N, P_2O_5 and K_2O + FYM @ 10 t ha^{-1})	81.23	42.63	47.63	41.15	53.16	85.20	45.56	50.65	43.47	56.22
T_4 (75% recommended dose N, P_2O_5 and K_2O + Neemcake @ 1 t ha^{-1})	76.73	40.17	45.26	38.84	50.25	79.80	43.76	46.81	42.10	53.12
T_5 (75% recommended dose N, P_2O_5 and K_2O + Bio-fertilizers)	79.36	40.81	45.94	39.99	51.53	82.55	44.56	49.61	42.82	54.89
Mean	76.59	40.17	45.22	38.84		79.67	43.68	48.25	42.06	
		At the same level of cropping sequence		At the same level of nutrient management			At the same level of cropping sequence		At the same level of nutrient management	
S.Em (±)		11.54		3.22			12.19		3.93	
C.D. (P = 0.05)		33.32		9.30			35.20		11.35	

TABLE 5. Economics as influenced by cropping sequences and integrated nutrient supply

Treatment	2013-14				2014-15			
	SP (t ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Return Re^{-1} invested	SP (t ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Return Re^{-1}invested
Cropping system								
Potato-cowpea-rice	76.59	268051	193372	2.60	79.67	318696	235775	2.85
Potato-green gram-rice	40.17	140602	78477	1.27	43.68	174704	106060	1.55
Potato-groundnut-rice	45.22	158256	92886	1.43	48.25	193000	120832	1.68
Potato-sesame-rice	38.84	135947	74922	1.24	42.06	166256	100730	1.50
S.Em (±)	1.76				1.65			
CD (P=0.05)	6.08				5.70			
Nutrient management								
T_1- 100% RD of NPK	48.60	170083	106531	1.63	52.08	208320	137911	1.91
T_2- 75% RD of NPK	47.49	166225	104971	1.67	50.78	203110	134870	1.93
T_3- 75% RD of NPK+ FYM @ 10 t ha^{-1}	53.16	186060	112854	1.50	56.22	224880	144595	1.76
T_4- 75% RD of NPK+ Neemcake @1tha^{-1}	50.25	175875	106450	1.49	53.12	212470	136007	1.74
T_5- 75% RD of NPK+ Bio-fertilizers	51.53	180338	118764	1.88	54.89	217040	150862	2.14

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 201-207, 2016

To Study the Different Nutrient Management and Cropping System on Soil Microbial Growth, Production, Rice Equivalent Yield and Monetary Returns in Different Rice Based Cropping Systems

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Published : 30.10.2017

Abstract

A field experiment was conducted during 2010-11 to 2012-13 at Jabalpur, Madhya Pradesh (India) to study the effect of nutrient management and cropping system on productivity and soil microbial growth under different rice based cropping systems in Madhya Pradesh. The 4 different cropping systems (CS_1 Green manuring sunhemp-Rice-Wheat, CS_2-Rice-Chickpea- Sesame, CS_3-Rice-Berseem, CS_4-Rice-Veg. pea-Sorghum) and three nutrient managements M_1- 100% Organic(1/3 N through each of FYM, Vermicompost and Neem oil cake), M_2 -100% Inorganic (100% NPK through fertilizers), M_3-INM (50% NPK through fertilizer + 50% N through organic sources) with 3 replications in Strip plot design. The soil of the experimental field was sandy clay loam in texture, neutral in reaction (7.3), normal EC (0.52), low in OC (0.72%), medium in available N (264.05kg/ ha) and P (12.8 kg/ha) and high in K (285.2 kg/ha). The growth of bacteria ($48.80 \times 10_5$), fungi ($41.65 \times 10_3$), azatobacter ($25.67 \times 10_3$), actinomycetes ($13.55 \times 10_3$) and phosphorous solublizing bacteria ($16.65 \times 10_3$) cfu g_{-1} soil was maximum in 100% inorganic nutrient management in rice berseem cropping system during the experiment and improved the rice equivalent yield of this cropping system.

Key words : Cropping systems, economic status, agronomic management, soil quality, yield.

Introduction

Rice and wheat are grown in a sequence on an area about 2.7 million hectares in Punjab and contribute 80% in the total food pool of the state of Punjab (DAGP, 2011). Madhya Pradesh is relatively underdeveloped with regards to agricultural productivity rural employment and economic status as compared to most of the Indian states. With the development of agricultural production, fertilization has been widely used as a common management practice to maintain soil fertility and crop yields (Shen, 2010). Long-term field experiments using different agronomic management can provide direct observations of changes in soil quality and fertility and can be predictions of future soil productivity and soil environment interactions. Over past decades, a great number of long-term experiments were initiated to examine the effects of fertilization on soil fertility in the world. Some studies have documented that the use of fertilizers was necessary and that continuous fertilizer application increased the concentrations of soil organic carbon, total nitrogen and other nutrients in plough layers compared with the initial value at the beginning of the experiment (Huang *et al*., 2010). Manure amendments markedly increased the contents of soil organic carbon, total nitrogen and other available nutrients and reduced soil acidification (Li *et al*., 2011). However, other studies have shown that the continued use of fertilizers may result in the decline of soil quality and productivity (Kumar *et al*., 2001). Long-term application of fertilizer helps to maintain the growth of micro organism growth in soil in rice-wheat cropping system (Bahadur *et al*., 2012).

Materials and Methods

The present study was conducted during 2010-11 to 2012-13 at the Research Farm of Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur (M.P.), India on a sandy clay loam soil. The soil of the experimental site had a pH 7.4, EC 0.51 dS/m and organic carbon 0.7%. The available soil nitrogen, phosphorus and potash were 264, 12.6 and 282 kg/ha, respectively. The bulk density of the soil was 1.35 Mg/m3. The factors studied included 3 nutrient management practices *viz.*, 100% organic (NM1), 100% inorganic (NM2) and integrated nutrient (NM3) and 4 cropping systems *viz.*, CS1 green manuring- ricedurum wheat, CS2- rice-chickpea-sesame, CS3- riceberseem (fodder + seed), CS4 - rice-vegetable peasorghum (fodder) in strip plot design with 3 replication. The crop varieties grown were Pusa sugandha Basmati- 5 in rice, MPO-1106 in durum wheat, JG-24 for gram, JB-1 for berseem, Arkel for vegetable pea during winter season and TKG-55 in sesame and MP Chari in sorghum during summer season. These crops were raised with recommended agronomic practices. In organic manure treatment nutrients were applied through farm yard manure. The manure was applied on the nitrogen equivalent basis for each crop. The nutrient composition of FYM was 0.5, 0.25, 0.5% N, P2O5 and K2O respectively. For the weed management, mechanical measures were adopted and for insect pest management, neem oil (Azadiractin 0.03%) was applied as and when required under organic nutrient management. In chemical fertilizer treatment, nutrient was applied through chemical fertilizers *viz.*, urea, and single super phosphate muriate of potash while plant protection was done through recommended pesticides, when required. The recommended dose of fertilizers for rice, wheat, chickpea, sesame, vegetable pea, sorghum and berseem. 120:26.4:33.3, 120:26.4:33.3, 20:60:30, 30:60:30, 20:26.4:16.6, 100:22:25 and 20:26.4:16.6 kg N: P: K/ha.

Results and Discussion

Effect on total bacterial count

The microbial population of the experimental soil accelerated upon receiving nutrients either through chemical fertilizer, organic manure or integrated nutrient management (table 1). The population of total bacteria ranged from 42.06 × 105 to 45.50 × 105 cfu g-1 soil. Significant increase in bacterial population was recorded under 100% inorganic NM2 plots. As such maximum population of total bacterial count was observed in 100% inorganic NM2 (48.10, 48.06 and 47.10 × 105 cfu g-1 soil) followed by integrated NM3 (46.23, 46.10 and 45.98×105 cfu g-1 soil) during three the years. The population of total bacterial count was minimum (45.90, 45.60 and 44.70 × 105 cfu g-1 soil) in 100% organic NM1, respectively. The growth of total bacterial count was influenced by different cropping systems. The maximum growth of total bacterial count was observed in CS3 rice-berseem cropping system (46.88 and 46.90 × 105 cfu g-1 soil) followed by all other treatments. The growth of total bacterial count was similar in rice-vegetable pea-sorghum CS4, green manuring-rice-wheat cropping system CS1 and rice-chickpea-sesame cropping system CS2 and did not showed marked difference. Therefore, in this treatment the population of bacteria was improved over initial.

Effect on fungi

Growth of fungi was significantly affected due to different nutrient management practices during both the years. It was observed that when the plots were applied with 100% inorganic NM2 the population of fungi was maximum (41.62, 41.32 and 40.80 × 103 cfu g-1 soil). Whereas, similar growth of fungi was observed in integrated NM3 and 100% organic NM1 during three the years. The different cropping showed remarkable decrease in population of fungi during three the years. The maximum growth of fungi was observed in (41.89, 42.10 and 42.38 × 103 cfu g-1 soil) CS3 rice berseem cropping system which was at par to all other treatments. The other cropping systems CS4, CS1 and CS2 did not marked any significant differences. The minimum growth of fungi was observed under CS2 rice-chickpea-sesame cropping system (37.96, 37.25 and 38.40 × 103 cfu g-1 soil).On an average the growth was more during second year as compared to first year but more as compared to initial.

Table 1. To study the nutrient management and cropping system on microbial population in soil after harvest and rice equivalent yield (mean of three years)

Treatments	Total bacterial count (105 × cfu g-1 soil)			Fungi (105 × cfu g-1 soil)			Azatobacter (103 x cfu g-1 soil)		
	2010-11	2011-12	2012-13	2010-11	2011-12	2012-13	2010-11	2011-12	2012-13
Nutrient Management									
NM1-100% organic (1/3 N through each of FYM, Vermicompost and Neem oil cake)	45.90	45.60	44.70	40.72	40.52	40.15	23.24	23.29	23.45
NM2-100% Inorganic (100% NPK through fertilizers)	48.10	48.06	47.10	41.65	41.32	40.80	25.42	25.55	25.67
NM3-Integrated Nutrient Management (50% NPK through fertilizer + 50% N through organic sources)	46.23	46.10	45.98	41.02	40.98	40.67	25.05	25.16	25.19
SEm±	**1.65**	**1.60**	1.62	**1.64**	1.60	1.69	0.85	0.92	0.68
CD(P=0.05)	4.80	4.77	4.15	4.88	4.52	4.32	2.27	2.18	2.08
Mean	46.74	46.59	45.93	41.13	40.94	40.54	24.57	24.67	24.77
Cropping System									
CS1-Green manuring (sunhemp)- rice (Pusa Sugandha 5)- wheat (MPO 1106)	42.48	42.55	42.72	37.92	38.62	38.70	23.55	23.92	24.01
CS2-Rice (Pusa Sugandha 5)- chickpea (JG 322)-sesame (TKG 55)	42.06	42.22	42.28	37.96	38.25	38.40	23.35	23.72	23.85
CS3-Rice (Pusa Sugandha 5)-berseem (JB 5) (fodder+seed)	46.72	46.92	47.00	41.89	42.10	42.38	25.10	25.50	25.62
CS4-Rice (Pusa Sugandha 5)-vegetable pea (Arkel)-sorghum (MP Chari) (fodder)	45.49	45.62	45.69	40.60	41.05	41.12	25.09	25.42	25.55
SEm±	1.61	1.70	1.52	1.52	1.66	1.67	0.52	0.69	0.62
CD(P=0.05)	4.92	5.00	4.62	4.85	4.74	4.55	1.65	1.97	1.88
Mean	44.19	44.33	44.42	39.59	40.01	40.15	24.27	24.64	24.76

Effect on azatobacter

The nutrient management did not recorded much effect on growth of azatobacter. Whereas, maximum population of azatobacter was observed under 100% inorganic NM2 (25.42, 25.55 and 25.67 × 103 cfu g-1 soil), which was followed by integrated NM3 (25.05, 25.16 and, 25.19 × 103 cfu g-1 soil). The minimum growth of azatobacter was observed in 100% organic NM1 (23.24, 23.29 and 23.45 × 103 cfu g-1 soil) during three years which was more than initial value. The rice-berseem cropping system CS3 recorded the maximum growth of azotobacter (25.10, 25.50 and 25.62 × 103 cfu g-1 soil) which was superior over all other cropping systems but similar to CS4 rice-vegetable pea sorghum (25.09, 25.42 and 25.55 × 103 cfu g-1 soil). The CS1 and CS2 system had relatively similar growth of azotobacter.

Effect on actinomycetes

The actinomycetes showed adverse effect on its population due to different nutrient management practices. The maximum population of actinomycetes was observed in 100% inorganic NM2 (13.25, 13.48 and 13.55 × 103 cfu g-1 soil) during three years. Whereas, its growth decreased in other nutrient management practices NM3 and NM1. The maximum population of actinomycetes was observed in CS3 rice-berseem cropping system (13.52, 13.66 and 13.76 × 103 cfu g-1 soil). Minimum growth of actinomycetes was observed in CS2 rice-chickpea-sesame cropping system (11.12, 11.38 and 11.48 × 103 cfu g-1 soil).

Effect on PSB

The PSB showed adverse effect on its population due to different nutrient management practices. The maximum population of actinomycetes was observed in 100% inorganic NM2 (16.65, 16.50 and 16.12 × 103 cfu g-1 soil) during three years. Whereas, its growth decreased in other nutrient management practices NM3 and NM1. The maximum population of actinomycetes was observed in CS3 rice-berseem cropping system (16.19, 16.68 and 16.82 × 103 cfu g-1 soil). Minimum growth of actinomycetes was observed in CS2 rice-chickpea-sesame cropping system (15.12, 15.58 and 14.72 × 103 cfu g-1 soil).

Effect on rice equivalent yield

The growth of different soil micro organisms showed remarkable influence on yield of different crops. Thus due to this the yield of different crops was influenced under different nutrient management and cropping systems. The maximum rice equivalent yield was observed in 100% inorganic NM2 (68.85 q ha-1), which was at par to integrated NM3 (66.20 q ha-1) and 100% organic NM1 (60.30 q ha-1). The maximum rice equivalent yield was obtained in rice-berseem cropping system CS3 (77.82 q ha-1) and minimum in CS2 ricechickpea- sesame cropping system (51.08 q ha-1). And the yield in CS4 and CS1 were more than CS2.

Effect on production efficiency

The production efficiency of 100% inorganic nutrient management was the maximum (23.12 kg ha-1 day-1) which was at par with INM (21.16 kg ha-1 day-1) and 100% organic nutrient management (18.87 kg ha-1 day-1). The rice-berseem cropping system recorded the higher production efficiency of (26.45 kg ha-1 day-1) followed by rice-vegetable pea-sorghum (21.06 kg ha-1 day-1), green manuring-rice-wheat (20.78 kg ha-1 day-1) and rice-chickpea-sesame (15.74 kg ha-1 day-1) as also reported by (Shah *et al.* 2013) and (Upadhyay *et al.* 2011).

Effect on gross monetary return

Out of 3 nutrient management practices 100% organic nutrient management fetched the highest gross monetary return of 168532 Rs ha-1 year-1, which declined as 162710 and 151576 Rs ha-1 year-1 due to 100% inorganic nutrient management and integrated nutrient management as on required as given in table 3. Among the 4 cropping system tested, rice-chickpea-sesame cropping system led to record the lowest gross monetary return (132403 Rs ha-1 year-1), which increased as 149722, 171983 and 189649 Rs ha-1 year-1 with rice-vegetable pea-sorghum (fodder) cropping system, green manuring-rice-wheat cropping system

Table 2. To study the nutrient management and cropping system on microbial population in soil after harvest and rice equivalent yield (mean of three years)

Treatments	Actinomycetes (10_3 x cfu g-1 soil)			PSB (10_3 x cfu g-1 soil)			Rice equivaent yield (qha^{-1})	production efficiency (kg ha-1 day-1)
	2010-11	2011-12	2012-13	2010-11	2011-12	2012-13		
Nutrient Management								
NM1-100% organic (1/3 N through each of FYM, Vermicompost and Neem oil cake)	11.68	11.62	11.70	14.82	14.53	14.09	60.30	18.87
NM2-100% Inorganic (100% NPK through fertilizers)	13.25	13.48	13.55	16.65	16.50	16.12	68.85	23.12
NM3-Integrated Nutrient Management (50% NPK through fertilizer + 50% N through organic sources)	12.35	12.55	12.69	15.40	15.60	13.72	66.20	21.16
SEm±	0.96	0.87	0.58	0.67	0.63	0.72	2.19	0.41
CD(P=0.05)	2.14	2.14	1.49	1.59	1.74	1.84	9.02	0.98
Mean	12.43	12.55	12.65	15.62	15.54	14.64	65.12	21.05
Cropping System								
CS1-Green manuring (sunhemp)- rice (Pusa Sugandha 5)- wheat (MPO 1106)	11.09	11.55	11.72	15.22	15.40	15.50	60.85	20.78
CS2-Rice (Pusa Sugandha 5)- chickpea (JG 322)- sesame (TKG 55)	11.12	11.38	11.48	15.12	15.58	14.72	51.08	15.74
CS3-Rice (Pusa Sugandha 5)-berseem (JB 5) (fodder+seed)	13.52	13.66	13.76	16.19	16.68	16.82	77.82	26.45
CS4-Rice (Pusa Sugandha 5)-vegetable pea (Arkel)- sorghum (MP Chari) (fodder)	12.35	12.48	12.62	14.08	14.50	15.62	69.02	21.06
SEm±	0.82	0.80	0.98	1.02	1.07	1.24	8.92	2.42
CD(P=0.05)	2.08	2.19	2.35	2.48	2.78	2.83	22.6	6.15
Mean	12.02	12.27	12.40	15.15	15.54	15.67	64.69	21.01

Table 3. to study the different nutrient management and cropping systems on mean gross monetary returns (Rs ha-1 year-1).

Treatments	CS1 -Green manuring-rice-wheat	CS2 -Rice - chickpea-sesame	CS3 -Rice-berseem (fodder+seed)	CS4 -Rice-veg. pea-sorghum (fodder)	Mean
NM1 100% organic (1/3 N through each of FYM, Vermicompost and Neem oil cake)	181914	137823	195423	158968	**168532**
NM2 100% Inorganic (100% NPK through fertilizers)	172549	134556	193657	150076	**162710**
NM3 Integrated Nutrient Management (50% NPK through fertilizer + 50% N through organic sources)	161487	124829	179867	140122	**151576**
Mean 171983	**132403**	**189649**	**149722**		

and rice-berseem (fodder+seed) cropping system, respectively. While considering the effect of treatment combinations rice-berseem (fodder+seed) cropping system with 100% organic nutrient management led to record maximum gross monetary return of 189649 Rs ha1 year-1, but it was minimum (132403 Rs ha-1 year-1) under rice-chickpeasesame cropping system with integrated nutrient management. The nutrient management and cropping system effected the growth of micro organisms and it ultimately resulted in increasing the crop yield in different cropping systems. Therefore, it can be concluded that application of 100% organic nutrient management in riceberseem (fodder+seed) cropping system was superior over all other treatments. It also resulted in better growth of microbes in soil.

Conclusion

The nutrient management and cropping system effected the growth of micro organisms and it ultimately resulted in increasing the crop yield in different cropping systems. Therefore, it can be concluded that 100% inorganic NM2 in rice-berseem cropping system CS3 was superior over all other treatments.

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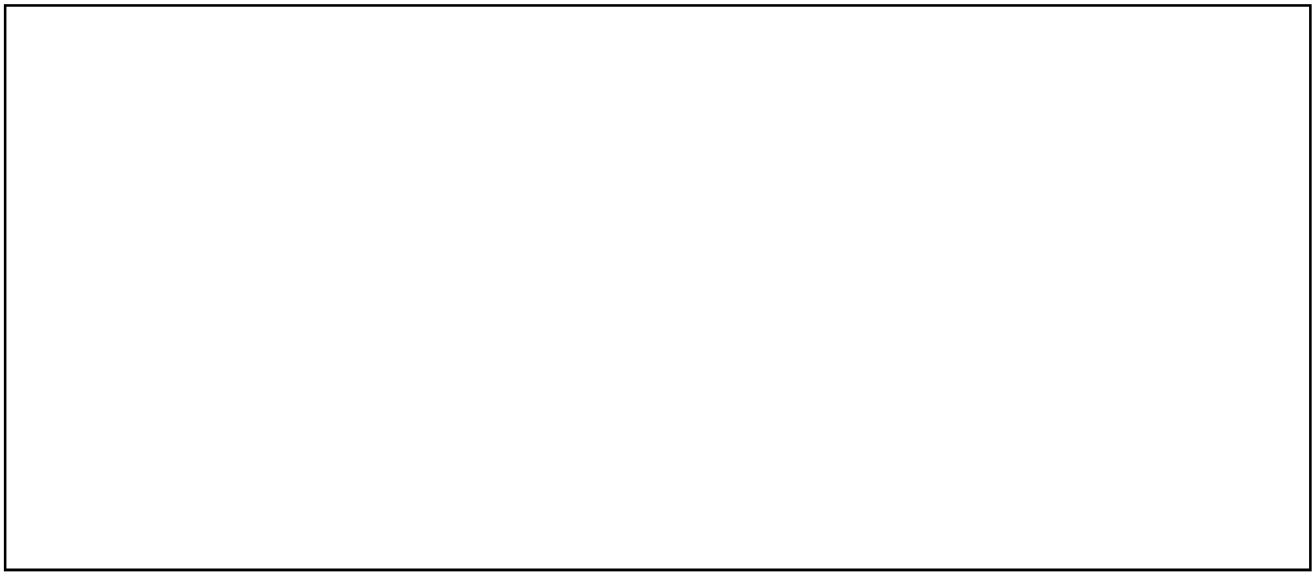

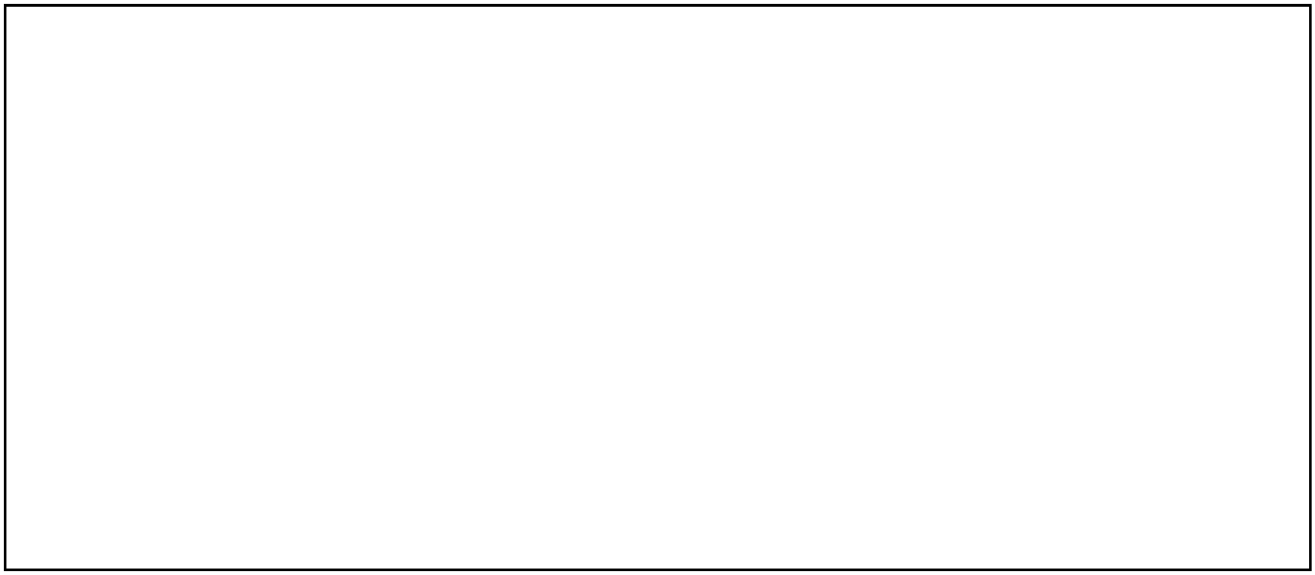

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 209-213, 2016

Effect of Nutrient Management Practices on Yield of Sunflower (*Helianthus Annuus* L.) Under Red and Lateritic Zones of West Bengal

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Published : 30.10.2017

Abstract

A field experiment was conducted to study the effect of nutrient management practices on yield of sunflower (*Helianthus annus* L.) under red and laterite zone of West Bengal during 2013-14 at Rice Research Station, Bankura, West Bengal, India on sandy loam soil of slightly acidic in reaction (pH: 5.4). Main objective was identifying the suitable nutrient management practices for sunflower in red and laterite zone of West Bengal. This experiment was conducted in randomized complete block design (RCBD) with three replications. Sunflower cv. Hybrid (KBSH-41) was used. Spacing was 60 cm x 30 cm. Spray of borax @ 0.2 % (2g/lit. of water) to capitulum at ray floret opening stage was done to improve seed set and seed filling. 1st, 2nd, 3rd and 4th irrigations at seedling, button, flowering and seed development stages, respectively were applied. The experimental results revealed that the highest seed yield of 2106 kg ha^{-1} was recorded from treatment N_9[N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] and it was statistically at par with that of 1950 and 1924 kg ha^{-1}, respectively which were obtained from treatment N_6 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %] and treatment N_8 [N_2 (N, P_2O_5, K_2O @ 80, 100, 100 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %], respectively. The lowest seed yield of 1027 kg ha^{-1} was obtained from treatment N_1 (N, P_2O_5, K_2O @ 60, 80, 80 kg ha^{-1}).

Key words : Sunflower, Nutrient management, Seed yield and Red & laterite zone

Introduction

The global area under sunflower is around 18 m ha with a total production about 22.07 m t and the productivity is 1129 kg ha^{-1}. In India, sunflower is relatively a recent introduction towards 70's and the present area is 2.7 m ha with a production of 10.86 lakh tonnes (Hedge, 2005). India is one of the four players in the vegetables oil scenario of the world, being one of the important oilseed grower, producer, importer and exporter. Oil seed form the second largest agricultural commodity after cereals in India, sharing 13 percent of the country's gross cropped area and accounting for nearly 5% of gross national product and 10% of the value of all agricultural products. Sunflower can be a promising crop (Chaterjee *et al*., 1972). It is interesting to note that sunflower is making inroads into the safflower and *rabi* or summer groundnut areas in northern Karnataka, Maharashtra and some parts of Andhra Pradesh. Now it has been found that sunflower is the suitable alternative for mustard (Dauley *et al*., 1974). It produces a very high yield of oil per unit surface area and per unit time. Sunflower can easily be grown in between two others crops due to its short growing period. Sunflower seed contain 40-45% high quality oil, which is light yellow in colour with pleasant flavours and excellent keeping quality. The oil is high poly-unsaturated fatty acids (68% linoleic acid). Sunflower is recommended as a dietary constituent to patient suffering from physiological disorders of the arteries which result heart attack. To meet up the ever-increasing demand for

vegetable oil, sunflower having the abovementioned advantages over other oilseed crops from the standpoint of quality and economics etc. has drawn our attention much. Cultivation of sunflower has started recently and has shown great prospects for growing in different parts of India. The present status regarding the cultivation of sunflower in West Bengal is very promising, not only the area, but also production and productivity of sunflower has increased by leaps and bounds since last 5 years.

Furthermore, in the light of the recent considerable increase in the price of the chemical fertilizers and the scarcity of foreign exchange in most developing countries, the large-scale use of organic material as plant nutrient source is a sound economic proposition. Balanced and integrated plant nutrient supply and management involving low doses of organic materials, compost/FYM/ vermin-compost is needed to enhance the use efficiency of native and applied micronutrients and for restoring soil fertility (Singh, 1999). Therefore, soil health and sustainable productivity depend mainly on how best the available organic inputs are managed in association with chemical inputs. On the other hand, sunflower is an energy reach and nutrient exhaustive crop requiring higher fertilization, especially N and P for its maximum production potential. The long term use of chemical fertilizers without organic manures or crop residues damages the soil physical properties (Biswas *et al*., 1971). The intensive cultivation with no organic material application causes a depleting trend of soil organic matter leading to decline in nitrogen reserve as well as low nutrient retention capacity owing to decreased C.E.C. (Lal and Kang, 1982). Over a period of time, it has become essential to fertilize the low organic matter soils not only with N, P and K but also micronutrients. Fertilizer use efficiency of micronutrients presently is only 2-5% (Singh, 1999). Till now, the average productivity of oilseed in India is only 935kg/ha, which is very low as compared to that of world, which is 1632 kg/ha (Pal and Gangwar, 2004). Therefore, present investigation was carried out with a view to develop a package involving nutrient management practices for the overall improvement of production and productivity of sunflower.

Materials and Methods

A field experiment was conduct to evaluate the 'Effect of nutrient management practices on yield sunflower (*Helianthus annuus* L) under red and laterite zone of West Bengal' at Rice Research Station (RRS), Bankura, West Bengal, India during *rabi* season of 2013-14. The soil of experimental field was sandy loam in texture with medium in fertility status. The experiment was laid out in randomized complete block design (RCBD) in 3 replications with nine levels of nutrient management practices [N_1 = N, P_2O_5, K_2O @ 60, 80, 80 kg ha^{-1}, N_2 = N, P_2O_5, K_2O @ 80, 100, 100 kg ha^{-1}, N_3 = N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}, N_4 = N_1 + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %, N_5 = N_2 + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %, N_6 = N_3 + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %, N_7 = N_1 + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %, N_8 = N_2 + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 % , N_9 = N_3 + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] were randomly allotted in block.Sunflower cv. Hybrid (KBSH-41) was used. Spacing was 60 cm x 30 cm. Spray of borax @ 0.2 % (2g/lit. of water) to capitulum at ray floret opening stage was done to improve seed set and seed filling. 1^{st}, 2^{nd}, 3^{rd} and 4^{th} irrigations at seedling, button, flowering and seed development stages, respectively were applied. Half (50%) N, entire phosphorus and half (50%) potassium was applied as basal. Remaining half of N in two splits at 30 and 55 DAS was applied. Remaining half of K at 30 DAS was applied and well mixed with soil after application. The source of N, P_2O_5 and K_2O were urea, S.S.P. and M.O.P., respectively. The experimental site represents low rainfall area (drought prone) of the West Bengal state with average annual rainfall of 1200-1400 mm. The soil of experimental field was sandy loam in texture with medium in fertility status. Oil content (%) of sunflower was determined by taking seed samples of 5 gm for each net plot. The seed were crushed in a mortar and transferred together with solvent washing of the mortar to a soxhelt apparatus for extraction of oil. Petroleum ether (boiling point 60 - 80 ^{0}C) was used as solvent. Petroleum ether was evaporated on a boiling water bath and the weight of the oil was then recorded after a constant weight obtained. From the weight of

oil, the oil content of seed was calculated using the formula. From the percentage of oil, the oil yield (kg ha^{-1}) was calculated by multiplying oil content with seed yield.

$$\text{Oil in \%} = \frac{\text{Weight of oil (g)}}{\text{Weight of samples (g)}} \text{ X } 100$$

Results and Discussion

The growth, yield attributes, seed and oil yield of sunflower grown during *rabi* season under different levels of nutrient management practices has been presented in Table 1 and 2. It was revealed that seed yield of sunflower was significantly influenced by levels of nutrient management practices. The treatment N_9 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] produced highest plant height at harvest (157.2 cm), maximum dry matter accumulation at harvest (137.8 g/plant), highest LAI at 90 days after sowing (DAS) (1.45), highest head diameter (23.5 cm), highest number of seeds/head (535.6) and maximum seed weight/head (26 g). The experimental results revealed that the highest seed yield of 2106 kg ha^{-1} was recorded from treatment N_9 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] and it was statistically at par with that of 1950 and 1924 kg ha^{-1}, respectively which were obtained from treatment N_6 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %] and treatment N_8 [N_2 (N, P_2O_5, K_2O @ 80, 100, 100 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %], respectively. Best nutrient management practices (Inorganic fertilizers + Organic sources + micronutrient application) favoured the growth and development of sunflower plant resulted increased growth and yield attributing characteristics of the crop favourably. Indeed, this favourable effect of best nutrient management practices on yield attributing characters had been reflected on the seed yield of sunflower. This could be attributed as a result of higher uptake and recovery of applied nutrients. This might be due to better root growth and proliferation and also opportunity to extract water and nutrients both from larger soil profile area, which in turn must have improved synthesis and translocation of metabolites to various reproductive structures of sunflower plant and better distribution of it into seed would always results in higher seed yield. The lowest seed yield of 1027 kg ha^{-1} was obtained from treatment N_1 (N, P_2O_5, K_2O @ 60, 80, 80 kg ha^{-1}) (Table 2).

Besides, the treatment N_9 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] produced highest oil content (45.6%). The experimental results revealed that the highest oil yield of 960.3 kg ha^{-1} was recorded from treatment N_9[N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] and it was statistically at par with that of 848.2 and 860.1 kg ha^{-1}, respectively which were obtained from treatment N_6 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %] and treatment N_8 [N_2 (N, P_2O_5, K_2O @ 80, 100, 100 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %], respectively. The lowest oil yield of 386.1 kg ha^{-1} was obtained from treatment N_1 (N, P_2O_5, K_2O @ 60, 80, 80 kg ha^{-1}) (Table 2). This result corroborated with the results obtained by Jadav *et al.* (1991), Nandhagopal *et al.* (2002), Vasudevan *et al.* (1997), Sakthivel and Irutharaj (1998) and Bharambe *et al.* (2000).

Conclusion

Significant effect of levels of nutrient management practices on seed and oil yield of sunflower was observed. Highest seed and oil yield was obtained when the sunflower crop nourished with treatment N_9 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %]. It was statistically at par with treatment N_6 [N_3 (N, P_2O_5, K_2O @ 100, 120, 120 kg ha^{-1}) + FYM @ 4 t ha^{-1} + Borax spray @ 0.2 %] and treatment N_8 [N_2 (N, P_2O_5, K_2O @ 80, 100, 100 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @ 0.2 %] respectively. Considering both the economy of nutrient management practices and soil health status, it may be concluded that treatment N_8 [N_2 (N, P_2O_5, K_2O @ 80, 100, 100 kg ha^{-1}) + Vermicompost @ 2 t ha^{-1} + Borax spray @

TABLE 1. Effect of nutrient management practices on growth and ancillary characters of sunflower during *rabi* season

Treatments	Plant height (cm) at harvest harvest	Dry matter accumulation (g/plant) at	Leaf area index (LAI) at 90 DAS	Head diameter (cm)	No. of seeds/head
N_1	92.5	72.7	1.04	8.5	285.2
N_2	106.2	79.5	1.08	9.1	320.7
N_3	115.3	88.6	1.18	10.2	385.2
N_4	123.5	92.2	1.24	11.7	420.7
N_5	130.8	98.4	1.33	16.7	480.6
N_6	140.2	105.1	1.37	20.6	510.5
N_7	133.4	115.7	1.41	14.2	470.2
N_8	142.3	124.4	1.43	18.5	505.3
N_9	157.2	137.8	1.45	23.5	535.6
S.Em (±)	10.2	0.93	0.06	1.3	21.1
CD (P=0.05)	30.7	2.8	0.18	3.9	63.5

TABLE 2. Effect of nutrient management practices on yield attributes, seed and oil yield of sunflower during *rabi* season

Treatments	Seed weight/head (g)	100-seed weight (g)	Oil content (%)	Seed yield (kg/ha)	Oil yield (kg/ha)
N_1	11.5	4.02	37.6	1027	386.1
N_2	13.2	4.13	39.4	1153	454.3
N_3	16.4	4.25	40.2	1375	552.7
N_4	18.1	4.31	41.8	1592	665.5
N_5	21.1	4.38	42.7	1815	775.1
N_6	22.6	4.42	43.5	**1950**	**848.2**
N_7	21.5	4.58	43.8	1785	781.8
N_8	23.3	4.62	44.7	**1924**	**860.1**
N_9	26.0	4.85	45.6	**2106**	**960.3**
S.Em (±)	1.1	0.45	0.37	78.06	42.9
CD (P=0.05)	3.3	NS	1.1	234.0	128.7

0.2 %] is best and better nutrient management practice for obtaining highest seed and oil yield of sunflower during *rabi* season under red and laterite zone of West Bengal.

Acknowledgement

The first author would like to thanks Dr. S. R. Patra, Joint Director of Agriculture (Research) and Dr. P. Bhattacharya, Director of Agriculture, Department of Agriculture, Govt. of West Bengal, Writers' Buildings, Kolkata - 700 001, West Bengal and Prof. B. K. Mandal, retired Professor & former Head, and Prof. P. Bandyopadhyay, Prof. B. C. Patra, Department of Agronomy, Bidhan Chandra Krishi Viswavidyalay, Mohanpur, Nadia, West Bengal, India for their valuable guidance and encouragement during the period of this research programme.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 215-218, 2016

Sustainable Yield Maximization Through Integrated Management Options in Medium Duration Pigeonpea

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Published : 30.10.2017

Abstract

A field experiment was conducted over two consecutive years (*kharif* 2014-15 and 2015-16) at the Centre for Pulses Research, OUAT, Berhampur, Odisha, to study the interactions of integrated management options for yield maximization in medium duration pigeonpea. The trial was laid out in RBD with three replications and 8 treatments viz. T1: INM (FYM @ 5t/ha + STBF i:e. NPKSZn + foliar Boron); T2 : IWM (pendimethalin (30 EC) 0.75kg/ha on 3 DAS + imazethapyr (10 SL) @ 100g ai/ha on 10-15 DAE of weeds + 1 HW on 50 DAS/ 1 inter cultivation on 50 DAS); T3: IPM (Neem Oil (1500 ppm) @ 3 ml/litre at bud initiation stage + Indoxacarb 15.8% EC @ 1ml/litre at the time of pod initiation stage + imidacloprid @ 0.3 ml/litre at 15 days after previous spray); T4: INM+IWM; T5: INM+IPM ; T6: IWM+IPM ; T7: INM+IWM+IPM ; T8: Control (Farmer's practices like 1 HW at 50 DAS + 50 % RDF + 1 spray of triazophos 40 EC @ 2ml/litre at 50 % flowering stage). Variety TTB-7 was sown in rainfed condition during *Kharif.* The pooled result revealed that the maximum plant height (179.5cm), number of primary fruiting branches/plant (9.23), number of pods/ plant (151.7), number of seeds/pod (3.80) and ultimately the highest grain yield (1674.5kg/ha) were recorded with the T7 (INM+IWM+IPM) which was 79.5% higher than that of control (933kg/ha). This treatment also registered highest net return (49,341/-). However, maximum B:C ratio (3.15) was obtained with T5 (INM+IPM). Prioritizing management options, IPM proved to be the first priority followed by INM and IWM in respect to grain yield & economics of pigeonpea. However, combined adoption of all management practices ie. INM, IWM and IPM together sustainably maximize the grain yield of medium duration pigeonpea.

Key words : Yield maximization, WCE, TDMP, HI, net return,

Introduction

Pigeonpea is one of the most ancient and versatile grain legume crop in India with 90% of global production and grown across the country under *Kharif* rain-fed upland ecosystem. Medium duration pigeonpea genotypes with 160-180 days duration are popular among Odisha farmers due to their high yield potentiality. The national productivity (approx. 800kg/ ha) lag far behind to its potential yield of 1500-3000kg/ ha. Pulses are indispensible for both human and soil health. It is apparent that major breakthrough in pulse production will have to be in rainfed areas as about 93% of total area under pulses is rainfed. Being a long duration crop and grown in marginal upland it needs better nutrient management (Sharma *et. al.,* 2010). Weeds compete with crop plants for resources, harbour pests and pose serious problems especially in early stage of crop growth causing yield loss to a tune of 32-65% in Pigeonpea. (Vaishya and Khan, 1989 ; Yadav and Singh, 2009). The slow growth habit of pigeonpea at initial stages along with wide row spacing, encourages rapid growth of weeds and leads to severe crop weed competition which finally reduces the crop yield. This protein rich crop is known to be affected by a number of pests with reported yield losses of 15-25% (Sharma *et. al.,* 2015). Pod borer complex is a major problem responsible for huge yield reduction in pigeonpea. Individual technologies for nutrient, weed and pest management in Pigeonpea are recommended. However, the interactions of these technologies and

cumulative effects are to be studied for prioritization and sustainable yield maximization in Pigeonpea.

Materials and Method

A field experiment was conducted under AICRP on Pigeonpea over two consecutive years (*kharif* 2014-15 and 2015-16) at the Centre for Pulses Research, OUAT, Berhampur, Odisha, which comes under East coast plains & hills agro-climatic zone of India and East & South Eastern Coastal Plain zone of Odisha with the objectives to study the interactions of integrated management options for yield maximization in medium duration pigeonpea in Odisha. The trial was laid out in Randomized Block Design with three replications and 8 treatments viz. T1: INM (FYM @ 5t/ha +STBF i;e: NPKSZn + foliar Boron) ; T2: IWM (pendimethalin (30 EC) 0.75kg/ha on 3 DAS + imazethapyr (10% SL) @ 100g ai/ha on 10-15 DAE of weeds + 1 HW on 50 DAS/ 1 inter cultivation on 50 DAS); T3: IPM (Neem Oil (1500 ppm) @ 3 ml/litre at bud initiation stage + Indoxacarb 15.8% EC @ 1ml/ litre at the time of pod initiation stage + imidacloprid @ 0.3 ml/litre at 15 days after previous spray); T4: INM+IWM; T5: INM+IPM ; T6: IWM+IPM ; T7: INM+IWM+IPM ; T8: Control (Farmer's practices like 1 HW at 50 DAS + 50 % RDF + 1 spray of triazophos 40 EC @ 2ml/litre at 50 % flowering stage) . Medium duration pigeonpea variety TTB-7 was sown in rainfed condition during *Kharif*. The soil was sandy loam with pH 6.1, low Organic Carbon (0.42 %), medium available Phosphorus (21.8kg/ha) and medium available potassium (181.7kg/ha), EC – 0.007 dS/m (Normal), Avl. S (kg/ha): 3.4(L), B (ppm): 0.32 (L) and Zn (mg/kg): 0.36(L). Observations on weed density (number/m2 and weed dry matter (q/ha) are taken at 70 DAS and pest (pod borer) infestation at harvest. Derived parameters like Weed Control Efficiency (WCE) are computed based on weed density as per 'A practical manual for weed management' by Sharma et al.(2009). Observations on growth (plant height), yield attributes and yield were recorded and analysed as per statistical procedure laid out by Gomez and Gomez (1984). Economics of the treatments were also calculated to find out the economic feasibility of the package.

Results and Discussion

Growth & Yield attributes :

The growth and yield attributes of pigeonpea were significantly affected by integrated management options (Table-1). The pooled result revealed that the maximum plant height (179.5cm) was recorded with T7 (INM+IWM+IPM) followed by T4 (170.8cm), which was significantly superior to that of control (140.8). The yield attributes such as number of primary fruiting branches/plant (9.23), number of pods/plant (151.7) and number of seeds/pod (3.80) were also found maximum with integration of all management options (T7). As compared to control this treatment recorded 47% higher primary fruiting branches per plant, 67% more pods per plant and 23% more seeds per pod.

Yield :

The grain, bhusa and stick yield of pigeonpea were also significantly influenced by different management options and their combinations (Table-1). It is observed from the data depicted in table-1 that, crop with single management option performed better than that of control. Similarly crop with two management options performed better than that with single management option. Ultimately the highest grain yield (1674.5kg/ha) was recorded with the crop with three management options, i:e: T7 (INM+IWM+IPM) which was 79.5% higher than that of control (933kg/ha).The highest bhusa yield (683.6 kg/ha), stick yield (2946.3 kg/ha) and Total Dry Matter Production (5304 kg/ha) were also registered with this treatment. Harvest index (HI) followed the same trend as that of grain yield and the maximum (0.316) was recorded with T7 as compared to 0.257 with the control.

Weed and Pest infestation :

The weed density (number/m2) and weed dry matter were taken at 70 DAS and weed control efficiencies of all treatments were computed (Table-2). It was observed that lowest weed density (36.2/ m2), weed dry matter (1.14q/ha) along with highest

Table 1. Growth, yield attributes and yield of pigeonpea as affected by integrated management options (pooled, 2014-16).

Treatment	Pl.ht. (cm)	No of br/ plant	No of Pod/ plant	No of seed/pod (kg/ha)	Grain yield control	% increase over	Bhusa yield (kg/ha)	Stick yield (kg/ha)	TDMP (kg/ha)	HI
T1: INM	166.9	7.82	128.1	3.6	1265.5	35.6	584.3	2739.8	4590	0.276
T2:IWM	158.1	7.63	115.7	3.5	1212.5	30.0	612.7	2545.2	4370	0.277
T3:IPM	152.6	7.60	123.3	3.7	1317.0	41.2	602.4	2761.5	4681	0.281
T4:INM+IWM	170.8	8.10	140.1	3.5	1449.5	55.4	633.8	2845.6	4929	0.294
T5:INM+IPM	166.8	8.38	139.0	3.8	1523.0	63.2	656.2	2863.7	5043	0.302
T6:IWM+IPM	154.8	8.32	131.7	3.7	1445.0	54.9	645.6	2818.7	4909	0.294
T7:I NM+ IWM + IPM	**179.5**	**9.23**	**151.7**	**3.8**	**1674.5**	79.5	**683.6**	**2946.3**	**5304**	**0.316**
T8:CONTROL	140.8	6.33	91.1	3.1	933.0	—	539.2	2159.1	3631	0.257
S.Ed.	7.44	0.61	6.45	NS	96.49		42.1	191.4	314.2	
CD(5%)	15.94	1.30	13.82		206.8		90.3	410.6	673.9	

Table 2. Influence of integrated management options on weed & pest infestation and economics of pigeonpea (Mean of two year).

Treatment	WD (number/m2) at 70DAS	WDM (q/ha) at 70 DAS	WCE (%)	% of infested pod at harvest	Grain yield (kg/ha)	Gross return (Rs./ha)	Cost of production (Rs./ha)	Net return (Rs/ha)	% increase over control	B:C Ratio
T1: INM	79.6	3.16	(-) 3.78	14.6	1265.5	55049	18,500	36549	48.7	2.98
T2:IWM	36.2	1.14	52.80	13.0	1212.5	52744	18,500	34244	39.3	2.85
T3:IPM	69.1	2.76	9.91	3.2	1317.0	57290	18,500	38790	57.8	3.10
T4:INM+IWM	48.3	1.73	37.03	10.2	1449.5	63053	21,000	42053	71.0	3.00
T5:INM+IPM	72.7	2.86	5.22	4.6	1523.0	66251	21,000	45251	84.1	3.15
T6:IWM+IPM	37.1	1.28	51.63	2.4	1445.0	62858	21,000	41858	70.3	2.99
T7: INM+IWM + IPM	47.7	1.71	37.81	3.1	1674.5	72841	23,500	49341	100.7	3.10
T8:CONTROL	76.7	3.04	00	13.2	933.0	40586	16,000	24586	—	2.54

WD: Weed Density; WDM: Weed Dry Matter; WCE: Weed Control Efficiency
NB: Cost of Pigeonpea grain was Rs.43.50/kg (MSP) during both the years.

WCE (52.80%) were obtained from the treatment with only IWM. When IWM combined with other integrated management options , especially with INM, the WCE found to be decreased. Maximum weed density, even more than farmers' practice (control) was recorded with only INM , which might be due to more nutrient availability. The percentage pod damage due to *Maruca spp*. and *Helicoverpa spp.* were computed at harvest. The data revealed that the lowest infestation was recorded with the treatments with IPM + IWM (2.4 %) followed by sole IPM treatment (3.2 %). Nevertheless, the highest damaged pod (14.6%) was recorded with the treatment with INM only.

Economics :

Economics of all the treatments were calculated and the highest net return (49,341/-) was registered with integration of three management options, i:e: T7 (INM+IWM+IPM) which was 100.7% higher than that of control (24,586/-). T5 (INM+IPM) with net return (45,251/-) was the next best treatment (Table-2). However, maximum B:C ratio (3.15) was obtained with T5 (INM+IPM). Prioritizing management options, IPM proved to be the first priority followed by INM and IWM in respect to grain yield & economics. Adoption of any single management option gave higher yield and net return than that of control. Similarly adoption of two management options proved better than that with single management option. Among combination of two management options, INM+IPM (T5) gave the highest grain yield (1523kg/ha), net return (45,251/-) and B:C ratio (3.15). Combined adoption of all management practices ie. INM, IWM and IPM together sustainably maximize the grain yield of medium duration pigeonpea.

Conclusion

i) Among management practices, IPM is the 1st priority to increase yield and get higher net return in pigeonpea through management of pod borer complex.

ii) Combination of IPM with INM (two management options) substantially recorded higher grain yield (63.2%) and net return (84.1%) than that of control.

iii) Combined adoption of all management practices ie. INM, IWM and IPM together sustainably maximized the grain yield (79.5% higher than control) and also gave highest net return (100.7% higher than control) in medium duration pigeonpea.

Acknowledgement

Authors are indebted to the AICRP on Pigeonpea for funding & project formulation. They are also grateful to the OUAT, Bhubaneswar for providing land, lab & other supports.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 219-223, 2016

Field Evaluation of Entomopathogenic Fungal Formulation, (*Verticillium Lecanii*) against Whitefly (*Bemesia Tabaci* Genn.) Infesting Tomato

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Published : 30.10.2017

Abstract

Verticillium lecanii 1.50% LF (Bio-Catch) entomopathogenic fungi was bio evaluated against whitefly on tomato in comparison with Neem extract conc. 5% w/w at Central Research Farm, BCKV, Gayespur, Nadia, West Bengal. Maximum mortality of whitefly (55.00%) was recorded from *Verticillium lecanii* 1.50% LF i.e Bio-Catch @ 4000 ml/ha which was statistically at par with same product @ 2000 ml/ha (48.22 %) and the Bio-Catch @ 1500 ml/ha was the next best treatment which registered 48.06 % mortality. Neem extract conc. 5% w/w @ 200 ml/ha and Thiamethoxam @ 200g/ha were comparatively less effective against whitefly recorded 44.65 % and 37.51 % mortality respectively. Significant higher yield of tomato 25.6 ton/ha (in the year 2014-15) and 26.35 t/ha (in the year 2015-16) was obtained through the protection by *Verticillium lecanii* 1.50% LF (Bio-Catch) @ 4000 ml/ha respectively.

Key words : Tomato whitefly, *Verticillium lecanii,* 1.50% LF (Bio-Catch), management.

Introduction

Tomato (*Lycopersicon esculentum* Mill) is one of the most important and remunerative vegetable crop (Ghimire *et al.,* 2000/2001) widely grown in different district of West Bengal and the annual production is 1204430 tonnes in area of 57170 hectares of land (NHRDF, 2015-16). There are several constraint led to limit tomato production in West Bengal. These are pests and diseases causing significant crop loss. There are series of pests such as aphid, jassid, whitefly, red spider mite, fruit borer (Lange and Bronson 1981). Among them whitefly is one of the serious pest in tomato field (Muniz and Nombela 2009). Damage caused by sucking of plant sap as well as transmission of plant viruses such as *Tomato Yellow* Leaf Curl Virus (Mehta *et al.,* 1994). In present scenario farmers are approaching hazardous pesticides to manage the pest of tomato but it causes contamination to soil and ground water and creating bad effect on the food chain and potential health concerns. In this context, *Verticillium lecanii,* fungi based product is available in power as well as liquid formulations and quite effective on insects which suck the plant sap on a variety of crops. It attacks all the stages of insect and is capable of infecting wide range of insects host across geographical and climatic locations. Like other microorganisms, entomopathogenic fungi have specific biological characteristics that influence their activity in the environment (Parker *et al.,* 2003). Mor *et al*., (1996) compared 35 strains of *V. lecanii* from hosts of different geographical location against *Bemisia tabaci* and found to be virulent to 83 percent larval population. In the year 1970s, *V. lecanii* was developed to control whitefly and other soft bodies' insects (Hamlem, 1979). Two important fungi, *Paecilomyces fumosoroseus* and *V. lecanii* were reported on whitefly (Nunez *et al*., 2008). Persistent chemical insecticides are now prohibited in most countries and replaced by less bio base pesticides (British Columbia, 2006). To manage this pest by using chemical pesticides during the fruit

bearing stage is quite difficult as the fruits are harvested at frequent intervals and this result there is huge possibility to retain toxic residues in the fruits which may cause human health hazards. The use of organochlorine and organophosphorous group of pesticide has been reported to pose a potential threat to all types of ecosystem (Nayar *et. al*., 1992). Different groups of insecticides have been recommended to control whitefly (Suryawanshi *et al*., 2000; Satpathy *et al*., 2004). But the effectiveness of biopesticides lik *Beauveria bassiana*, *Verticillium lecanii* and *Metarhizium anisopliae* against whitefly has been reported by Naik and Shekharappa (2009) whereas neem base pesticides has been elaborated by Dhanalakashmi and Mallapur (2011). Bio-pesticides are catching the chief focus of the researcher in the insecticides sector. Hence, keeping all these in view, the present investigation has been attempt to suitable measure with the use of microbial toxin *Verticillium lecanii* 1.50% LF (Bio-Catch) and neem based formulation.

Materials and Methods

To evaluate the bio-efficacy of *Verticillium lecanii* 1.50% LF (Bio-Catch) against White fly, *Bemisia tabaci,* a field experiments was conducted at the Central Research Farm, BCKV, Gayespur, Nadia. The field trial was laid out during rabi season (2014-15 and 2015-16) in randomized block design (RBD) with six treatments including an untreated control with four replications in an area of plot size 20 m^2. One of the popular variety and farmer's choice Patharkuchi was selected. Standard Agronomic practices as per the recommendations were followed. After three weeks age seedlings were transplanted in the main-field. Instead of regular plant protection practices, a test bio-pesticide 'Bio-Catch' was sprayed at three different dosages two times at 15 days interval. These sprayings were started from 25 days after crop transplanting during dawn and dusk timings. All the precautions were taken before and during spraying so as the product should reach the target pest. The observation data were recorded on randomly selected five plants in each replication marked with tags with required details. The data on the number of white fly nymphs were noted before first spray and after 7 and 14 days of each spray.

At each harvest the yield was recorded and noted separately in plot and each treatment furthermore yield data is converted to yield/ha. The collected data was subjected to ANOVA (Analysis of Variance) after suitable transformation to square root or arc sin values. *Verticillium lecanii* is an entomopathogen which invades the insect body. Fungal conidia attached to the insect body cuticle and after germination the hyphae penetrate the cuticle and develop in the insect's body. High humidity like this coastal ecosystem and free water is essential for conidia germination and infection establishes within 2 days. As the fungus is host specific the infected insects may live for three to five days after hyphal penetration and after death the conidiophores bearing conidia are produced on cadaver. To confirm the death of insect by *Verticillium lecanii* dead insects were collected plot wise and observed under laboratory conditions in Petri dishes for a maximum period of 7 days.

Results and Discussion

The experimental results showed that the initial population of whitefly was almost same in all the treatment, which varying from 8.05 to 9.65 per plant (Table 1). Efficacy of *Verticillium lecanii* 1.50% Liquid formulation (Bio-Catch) was observed after spraying at three different doses viz. 1500 ml, 2000 ml and 4000 ml/ha on the basis of reduction of nymphs population. However, maximum mean mortality of whitefly (55.00%) was recorded from *Verticillium lecanii* i.e Bio-Catch @ 4000 ml/ha which was statistically at par with Bio-Catch @ 2000 ml/ha (48.22 %) at 14 days after spray. Bio-Catch @ 1500 ml/ha was the next best treatment which registered 48.06 % mean mortality. Neem oil @ 200 ml/ha and Thiamethoxam @ 200g/ha were comparatively less effective against whitefly recorded 44.65 % and 37.51 % mortality respectively. At 15 days after spraying, the fungal formulation, *V. lecanni* 1.50% Liquid formulation i.e Bio-catch @ 4000 ml/ha recorded 69.34 % mortality though in that case slightly higher percent of mean mortality was observed. During the second year experiment, the pre-treatment count made one day before spraying indicated that there was no significant difference among the treatments.

TABLE 1. Bi - efficacy of *Verticillium lecani* 1.50% LF against Whitefly on tomato (1st year)

Treatments	Dosage (ml/ha)	Pre-treatment population/ plant	% mortality of whitefly (1st round spray)			% mortality of whitefly (2nd round spray)			
			7 DAS	14DAS	Mean % of mortality	7 DAS	14DAS	21 DAS	Mean % of mortality
T_1= Bio-catch	1500	9.15	38.98 (6.28)*	57.14 (7.59)	48.06 (6.94)	56.52 (7.55)	45.16 (6.76)	53.57 (7.35)	51.75 (7.22)
T_2= Bio-catch	2000	8.05	44.07 (6.68)	52.38 (7.27)	48.22 (6.97)	65.22 (8.11)	54.84 (7.44)	71.43 (8.48)	63.83 (8.01)
T_3= Bio-catch	4000	9.30	57.63 (7.62)	52.38 (7.27)	55.00 (7.45)	71.74 (8.50)	61.29 (7.86)	75.00 (8.69)	69.34 (8.35)
T_4= Neem extract conc. Azadirach. 5% w/w min	200	9.65	44.07 (6.68)	45.24 (6.76)	44.65 (6.72)	56.52 (7.55)	35.48 (6.00)	46.43 (6.85)	46.41 (6.80)
T_5= Thiamethoxam	200	8.60	44.07 (6.68)	30.95 (5.61)	37.51 (6.14)	39.13 (6.30)	32.26 (5.72)	32.14 (5.71)	34.51 (5.91)
T6= Untreated	-	9.40	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)
S.Em. . ±		NS	0.33	0.21	—	0.33	0.26	0.35	-
CD (0.05)			2.86	3.58	—	2.47	2.84	3.45	-

Values are mean of four replications,* values in parentheses are angular root transformed values;

TABLE 2. Bi - efficacy of *Verticillium lecani* 1.50% LF against whitefly on tomato (2nd year)

Treatments	Dosage (ml/ha)	Pre-treatment population/ plant	% mortality of whitefly (1st round spray)			% mortality of whitefly (2nd round spray)			
			7 DAS	14DAS	Mean % of mortality	7 DAS	14DAS	21 DAS	Mean % of mortality
T_1= Bio-catch	1500	9.15	40.11 (39.59)*	54.18 (47.68)	47.14 (43.65)	59.14 (50.56)	49.70 (45.15)	62.79 (52.70)	57.21 (49.44)
T_2= Bio-catch	2000	8.05	44.33 (42.03)	55.72 (48.57)	50.02 (45.30)	62.76 (52.69)	56.57 (49.05)	72.50 (58.69)	63.61 (53.20)
T_3= Bio-catch	4000	9.30	47.61 (43.92)	58.42 (50.14)	53.01 (47.01)	68.62 (56.24)	59.75 (50.92)	78.46 (62.70)	68.94 (56.44)
T_4= Neem extract conc. Azadirach. 5% w/w min	200	9.65	41.14 (40.19)	45.46 (42.68)	43.30 (41.44)	58.55 (50.22)	44.08 (41.89)	58.00 (49.89)	53.54 (47.32)
T_5= Thiamethoxam	200	8.60	41.53 (40.41)	39.56 (39.27)	40.54 (39.84)	45.45 (42.68)	36.04 (37.19)	45.97 (42.98)	42.48 (40.96)
T6= Untreated	-	9.40	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)	0.00 (4.25)
S.Em. . ±		NS	1.20	0.95	—	0.73	0.90	1.04	—
CD (0.05)			3.61	2.86	—	2.20	2.70	3.14	—

Values are mean of four replications,* values in parentheses are angular root transformed values;

Least mortality percent was recorded from the treatment T_5 i.e thiamethoxam @ 200ml/ha recorded 42.48 percent followed by T_4. While the treatments *Verticillium lecanii,* Bio-catch @ 1500, 2000 and 4000 ml/ha maintained whitefly population below the damage level. Similar trend of result has been found at second round of spray though in that case slightly higher percent of mortality was observed. Similar results were obtained by (Sharma *et al.* 2015), (NARC 2011) (Cuthbertson at al. 2005) and (Nier *et al.* 1993) they were found that the used of *V. lecanni* reduced whitefly population by 93.55 to 90.84 percent.

Tomato yield:

The data on tomato fruit yield revealed that all the treatments were significantly superior over untreated control (Table-3). However, highest fruit yield was obtained from *Verticillium lecanii* 1.50% Liquid formulation (Bio-Catch) @ 4000 ml/ha (25.50 t/ha). The next best yield was recorded from Bio-Catch @ 2000 ml/ha (23.81 t/ha) followed by Bio-Catch @ 1500 ml/ha (22.94 t/ha) and Thiamethoxam @ 200g /ha (22.52 t/ha). The fruit yield of tomato showed that application of *Verticillium lecanii* 1.50% Liquid formulation (Bio-Catch) at all three doses increased from 14.41 to 24.76 % over untreated control in the first year and 13.28-25.92% in the second year experiment (Table-3).

Conclusion

The studies on bioefficacy of *Verticillium lecanii* 1.50% Liquid formulation (Bio-Catch) on tomato for the control of white fly, *Bemisia tabaci* confirmed that Bio-Catch applied @ 2000 ml/ha is equally effective to higher dosage 4000 ml/ha. Fruit yield of tomato also increased in the plots treated with this formulation. Therefore, Bio-Catch @ 2000 ml/ha is suggested to control white fly in tomato.

Acknowledgement

With provide special thanks and gratitude to the Hon'ble Vice Chancellor and Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, for providing infrastructure facilities. I am also thankful

Table 3. Impact of *Verticillium lecani* 1.50% LF on fruit yield of Tomato

Treatments	Dose g or ml/ha	1st year yield (2014-15) Yield kg/plot	Yield t/ha	Yield increase over control (%)	2nd year yield (2015-16) Yield kg/plot	Yield t/ha	Yield increase over control (%)
T_1= Bio-catch	1500	44.81 (6.69)	23.4	14.41	45.88 (6.77)*	22.94	13.28
T_2= Bio-catch	2000	49.66 (7.04)	24.8	21.13	47.63 (6.90)	23.81	17.60
T_3= Bio-catch	4000	51.15 (7.15)	25.6	24.76	51.00 (7.14)	26.35	25.92
T_4= Neem extract conc. Azadirach. 5% w/w min	200	44.06 (6.63)	22.0	7.45	44.74 (6.69)	22.37	10.47
T_5= Thiamethoxam	200	43.28 (6.57)	21.6	5.55	44.74 (6.69)	22.52	11.23
T6= Untreated	-	40.90 (6.39)	20.5	-	40.50 (6.36)	20.25	—
SED ±		0.77	-	-	0.08	—	—
CD (p=0.05)		2.26	-	-	1.84		

Values are mean of four replications; values in parentheses are square root transformed values

to the Department, as well as field staffs of Central Research Farm, BCKV., whose have contributed to it.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 225-236, 2016

Effect of Spacing, Dates of Haulm Cutting and Fertility Levels on Quality Seed Grade Tuber Production of Potato (*Solanum Tuberosum* L.) Under Lower Gangetic Plains of West Bengal

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Published : 30.10.2017

Abstract

Field experiments were conducted during rabi seasons of 2015-16 and 2016-17 at C-unit research farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to determine the effects of spacing, dates of haulm cutting and fertility levels on quality seed grade tuber production of potato (Solanum tuberosum L.) under lower Gangetic plains of West Bengal. The experiment was laid out in a split plot design with three replications having twelve treatment combinations. The results revealed that emergence of potato variety Kufri Himalini was not significantly affected by spacing, dates of haulm cutting, fertility levels and their interactions. Spacing and dates of haulm cutting had no significant effect on plant height and no. of shoots per plant but these were significantly affected by fertility levels. With the decrease in intra row spacing from 20cm to 10cm seed grade size (< 75g) tuber yield and numbers and total tuber numbers were significantly increased but marketable grade (> 75 g) tuber yield and numbers were significantly reduced, lower spacing also increased the 0-25g grade and 25-50g grade tuber yield. Dehaulming at 65 DAP increased the seed grade size (<75g) tuber yield and numbers over haulm cutting at 75 DAP. With the decrease in fertility levels from 100% RDF of NPK to 50% RDF of NPK the seed grade (< 75 g) tuber production and number were significantly increased but marketable grade tuber yield (> 75 g) and numbers were significantly decreased. It was also revealed that, with the decrease in fertility levels from 100% RDF of NPK to 50% RDF of NPK the total tuber yield was significantly reduced but it significantly increased the total tuber numbers. Both spacing and fertilizer dose had a marked effect on disease incidence and severity. Early blight incidence and intensity was increased with decreasing fertilizer dose. Dehaulming at 65 DAP was found to be safer so far as infestation and chances of viral disease transmission by the sucking pests were concerned as up to 10th January no aphid infestation was noticed in both the years of study.

Introduction

West Bengal is the second largest potato growing state in India with a production of 9.0 million tonnes from an area of 409.7 thousand hectares, while the productivity was 22.02 t ha^{-1} during 2013-14 (Directorate of Agriculture, WB, 2014). The state accounts for one-third of the country's total potato production. Potato is the most popular crop in West Bengal next to the cereals. The crop is mostly grown during winter season (November-March) with short day conditions (10-11 hr sunshine). Seed tuber is the single most important factor in potato cultivation, which accounts for nearly 40-50% of the total investment for raising the crop, and if the seed is not of good quality, then optimum production could not be achieved. Unavailability of good quality seed, high price and untimely supply of seed at the village level are the main limiting factors for increase of potato production. It is well established that quality seed alone can contribute more than 20% increase towards production. With the expansion of potato cultivation in the Indo-Gangetic plains (IGP), it became evident that seed production in the Indian hills can not cope with the increasing demand of good quality seed. Moreover, quarantine of seeds produced in Darjeeling area due to wart and Nilgiri hills

due to cyst nematode infestations seriously restricted opportunities of seed production in the hills. The seed produced from the western hills of Himachal Pradesh, Jammu and Kashmir and Uttarakhand also suffered from problems of true dormancy, tedious transportation and rottage due to late blight infection in tubers. Therefore, an alternate seed production technology was urgently required to sustain the growing potato acreage in the plains. In West Bengal districts like Hooghly, Burdwan, some parts of Bankura and West Midnapur, and Birbhum are ideal for potato seed production because such areas are dry in nature and have prolonged winter than do the other districts in West Bengal. Moreover, the critical level of aphid population (20 aphids/100 compound leaves) generally appears on 2nd week of January onwards. As a result 8-9 weeks of low aphid pressure period is available, and the problem of viral diseases is much during this period. The seeds can also be produced in the districts like Burdwan, Hooghly and Nadia if early planting is adopted. Presently, the farmers of the state have no other option but to depend upon the home grown seed or buy it from the cold stores, open market and seeds from other states at higher prices. In most of the cases, poor quality of seed material causes lower yield. The only solution left for the farmers of this state is to produce their own seed by following the 'Seed Plot Technique' (Wurr, 1978).

Keeping the above facts in view, this experiment was initiated with the objectives to study the effect of spacing, dates of haulm cutting and fertility levels on quality seed grade tuber production of potato through 'Seed plot technique' under lower Gangetic plains of West Bengal.

Materials and Methods

Field experiments were conducted for two years at C-unit research farm (Kalyani) of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India situated at 22º58' N latitude and 88º3'E longitude with an altitude of 9.75m above mean sea (MSL) during rabi 2015-16 and 2016-17. The soil of the experimental field was sandy loam in texture and slightly alkaline in reaction (pH 7.2) having an organic carbon content of 0.56%, 183.26 Kg available N ha^{-1}, 16.8 kg available P_2O_5 ha^{-1}, 132 kg available K_2O ha^{-1}. The experiment was laid out in a split plot design with three replications having twelve treatment combinations viz. two levels of spacing, A1- 60cm X 20cm and A2- 60cm X 10cm were applied in main plots. Two levels of dates of haulm cutting, B1- 65 days after planting and B2- 75 days after planting were applied in sub plots and three levels of fertility levels, C1- 100% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP, C2- 75% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP, C3- 50% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP were applied in sub sub plots with a plot size of 5 m X 3 m. Breeder seeds of potato variety Kufri Himalini was planted on 6th November, 2015-16 and 2016-17 maintaining proper seed plot techniques. Tubers weighing 30–40 g each were planted in the furrows with a depth of planting of 3–4 cm and finally covered with soil. The recommended dose of fertilizer was 200, 150, 150 kg N, P_2O_5, K_2O per ha. Nitrogen (N), phosphorus (P) and potassium (K) were applied through urea, single super phosphate and muriate of potash respectively. Half of nitrogen, full dose of phosphorus and potassium were applied as basal. Rest half N was top dressed at 30 days after planting (DAP) followed by earthing up. Pre-emergence application of Sencor (Metribuzin) @ 0.75 kg a.i. ha^{-1} was done at 3 DAP followed by 1 hand-weeding at 20 DAP to promote early crop growth. As a prophylactic measure, spraying (twice) with Dithane M-45 (Mancozeb) @ 0.2% at 40 and 60 DAP was done against late blight. Imidacloprid 17.8SL @0.03% was also sprayed (thrice) at 30, 40 and 60 DAP for controlling aphids and other sucking insects. Continuous monitoring and roughing was done. Dehaulming was done as per treatments. For B1 haulm cutting was done on 09.01.16 and 09.01.17, and for B2 haulm cutting was done on 20.01.16 and 20.01.17 and harvesting was done 10 days after haulm cutting, and the crop lines were opened with the help of plough. Potato tubers were dug out from each plot manually. Data on grade wise tuber number and yield and total tuber number and yield were recorded at harvest from each net plot area. Analysis of variance of the data in

the experimental design and comparison of means at pd $\leq$0.05 were carried out, using MSTAT-C software.

Results and Discussion

Effect on plant emergence, plant height and no. of shoots per plant

Experimental results revealed that plant emergence of potato was not significantly influenced by the treatments and their interactions (Table 1,2,3,4 and 5). It ranged from 98.90 to 100%. Experimental results also revealed that spacing and dates of haulm cutting had no significant effect on plant height and no. of shoots per plant of potato variety Kufri Himalini but these were significantly affected by fertility levels. Decrease in fertility levels from 100% RDF of NPK to 50% RDF of NPK significantly reduced the plant height and no. of shoots per plant of potato. However, the interaction effect of the treatments on plant height and no. of shoots per plant of potato were found statistically insignificant.

Effect on grade wise and total tuber yield

Experimental results revealed that, 50-75g grade and > 75 g grade tuber production of potato was significantly influenced by spacing (Table. 6). With the decrease in intra row spacing 50-75g grade tuber yield was significantly increased but > 75 g grade tuber yield was significantly reduced, lower spacing also increased the 0-25g grade and 25-50g grade tuber yield, which is desirable to produce more amount of seed grade size tuber production of potato. The result corroborated with the findings of Dua *et al.* (2008). However the effect of spacing on total tuber yield was found statistically insignificant. Haulm cutting at 65 DAP increased the seed grade size (<75g) tuber yield over haulm cutting at 75 DAP. However, haulm cutting at 75DAP significantly increased the marketable tuber (> 75 g) production. This result corroborated with the findings of Lal and Sahota (1983). The effect of dates of haulm cutting on total tuber yield was found statistically insignificant. Fertility levels had a significant effect on grade wise and total tuber yield of potato. With the decrease in fertility levels from 100% RDF of NPK to 50% RDF of NPK the seed grade (< 75 g) tuber production was significantly increased but marketable grade tuber yield (> 75 g), total tuber yield and dry weight yield of tubers were significantly decreased. This was in conformity with the results of Dua *et al.* (2008). The highest total tuber yield (32.06 t ha^{-1}) was recorded with 100% RDF of NPK. The results also revealed that interaction of spacing and fertility level had a significant impact on marketable (>75g grade) and total tuber yield of potato (Table 7). The highest marketable (18.30 t ha^{-1}) and total tuber yield (33.65 t ha^{-1}) of potato was recorded with 20 cm intra row spacing and 100% RDF of NPK. The lowest total tuber yield (24.80 t ha^{-1}) of potato variety Kufri Himalini was recorded with 20 cm intra row spacing and 50% RDF of NPK. However, the other interactions (Table 8,9 and 10) were found mostly non significant.

Effect on grade wise tuber numbers and total tuber numbers

Experimental results revealed that, grade wise tuber numbers and total tuber numbers of potato were significantly influenced by spacing (Table. 11). With the decrease in intra row spacing from 20cm to 10cm seed grade size (< 75g) tuber numbers and total tuber numbers were significantly increased but marketable grade (> 75 g) tuber number was significantly reduced, which is desirable to produce more numbers of seed grade size tuber of potato. The result corroborated with the findings of Dua *et al.* (2008). Haulm cutting at 65 DAP increased the seed grade size (<75g) tuber numbers and total tuber numbers of potato and significantly reduced the marketable grade (> 75 g) tuber numbers. Similar findings were also reported by Mahmud *et al.* (2009) and Garg *et al.* (1999). However, the effect of dates of haulm cutting on total tuber number was found statistically insignificant. Fertility levels had a significant effect on grade wise and total tuber numbers of potato. With the decrease in fertility levels from 100% RDF of NPK to 50% RDF of NPK the seed grade size (< 75 g) tuber numbers and total tuber numbers were significantly increased but marketable grade (>75g) tuber numbers were significantly decreased. Similar result was also reported by Dua *et al.* (2008). This result is desirable for potato seed tuber production as large size tubers (>80g) are discarded under potato seed tuber certification process.

TABLE 1. Main effects of spacing, dates of haulm cutting and fertility levels on emergence, plant height and no. of shoots per plant of potato (Pooled data of two years)

Treatment	Potato		
	Emergence (%)	Plant height(cm)	No. of shoots plant^{-1}
Levels of spacing			
A1	99.48	71.67	3.14
A2	99.49	70.83	3.10
$S.E_m$ (±)	**0.05**	**0.24**	**0.04**
CD(P=0.05)	NS	NS	NS
Levels of dates of haulm cutting			
B1	99.28	71.36	3.10
B2	99.69	71.14	3.14
$S.E_m$ (±)	**0.19**	**0.15**	**0.06**
CD(P=0.05)	NS	NS	NS
Levels of fertility			
C1	99.58	73.33	3.30
C2	99.60	71.08	3.12
C3	99.28	69.34	2.94
$S.E_m$ (±)	**0.19**	**0.30**	**0.05**
CD(P=0.05)	NS	0.90	0.15

TABLE 2. Interaction effect of spacing and fertility levels on emergence, plant height and no. of shoots per plant of potato (Pooled data of two years)

Treatment	Potato		
	Emergence (%)	Plant height(cm)	No. of shoots plant^{-1}
(A1C1)	99.45	74.32	3.38
(A2C1)	99.72	72.33	3.23
(A1C2)	99.53	71.08	3.08
(A2C2)	99.67	71.08	3.15
(A1C3)	99.47	69.60	2.97
(A2C3)	99.08	69.08	2.92
$S.E_m$ (±)	**0.27**	**0.42**	**0.07**
CD(P=0.05)	NS	NS	NS

The results also revealed that interaction of spacing and fertility level had a significant impact on total number of potato tuber per hectare (Table 12). The highest total number (719445 nos. ha^{-1}) of potato tuber was recorded with 10 cm intra row spacing and 50% RDF of NPK. The lowest total tuber numbers (498611 nos. ha^{-1}) of potato variety Kufri Himalini was recorded with 20 cm spacing and 100% RDF of NPK. However, the other interactions (Table 13,14 and 15) were found mostly non significant.

TABLE 3. Interaction effect of spacing and dates of haulm cutting on emergence, plant height and no. of shoots per plant of potato (Pooled data of two years)

Treatment	Potato		
	Emergence (%)	Plant height (cm)	No. of shoots plant^{-1}
(A1B1)	99.29	71.94	3.13
(A2B1)	99.27	70.78	3.08
(A1B2)	99.68	71.39	3.16
(A2B2)	99.71	70.89	3.12
$S.E_m$ (±)	**0.26**	**0.22**	**0.08**
CD(P=0.05)	NS	NS	NS

TABLE 4. Interaction dates of haulm cutting and fertility levels on emergence, plant height and no. of shoots per plant of potato (Pooled data of two years)

Treatment	Potato		
	Emergence (%)	Plant height (cm)	No. of shoots plant^{-1}
(B1C1)	99.35	73.48	3.24
(B2C1)	99.82	73.17	3.37
(B1C2)	99.37	71.43	3.15
(B2C2)	99.83	70.73	3.08
(B1C3)	99.12	69.17	2.92
(B2C3)	99.43	69.52	2.97
$S.E_m$ (±)	**0.27**	**0.42**	**0.07**
CD(P=0.05)	NS	NS	NS

Disease incidence

In this experiment late blight was not observed at all in both the years of study (Table 16) because in both the years the crop was dehaulmed before appearance of late blight. As far as leaf spot disease is concerned both phoma and early blight was observed. Both spacing and fertilizer dose had a marked effect on disease incidence and severity. Highest phoma leaf spot incidence (15.00%) and intensity (3.20%) was observed when spacing was 60cm X 20cm and 100% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP. With same spacing the disease incidence and intensity decreased with decreasing dose of fertilizers i.e. 75% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP and 50% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP respectively. When the spacing was increased to 60cm X 20cm from the spacing 60cm X 10cm the disease incidence and intensity started decreasing. Minimum disease incidence (6.65%) and intensity (1.50%) was observed when the spacing was 60cm X 20cm with 50% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP. But in case of early blight, the disease incidence and intensity was increased with decreasing fertilizer dose. Barclay *et al.* (1973) also reported that both high nitrogen and low phosphorus treatments significantly reduced the incidence of early blight and the combination of high nitrogen and low phosphorus

Table 5. Interaction effects of spacing, dates of haulm cutting and fertility levels on emergence, plant height and no. of shoots per plant of potato (Pooled data of two years)

Treatment	Potato		
	Emergence (%)	Plant height (cm)	No. of shoots plant^{-1}
(A1B1C1)	99.27	74.53	3.25
(A1B1C2)	99.27	71.70	3.13
(A1B1C3)	99.33	69.60	3.00
(A1B2C1)	99.63	74.10	3.50
(A1B2C2)	99.80	70.47	3.03
(A1B2C3)	99.60	69.60	2.93
(A2B1C1)	99.43	72.43	3.23
(A2B1C2)	99.47	71.17	3.17
(A2B1C3)	98.90	68.73	2.83
(A2B2C1)	100.00	72.23	3.23
(A2B2C2)	99.87	71.00	3.13
(A2B2C3)	99.27	69.43	3.00
$S.E_m$ (±)	**0.38**	**0.60**	**0.10**
CD(P=0.05)	NS	NS	NS

Table 6. Main effects of spacing, dates of haulm cutting and fertility levels on grade wise and total tuber yield of potato (Pooled data of two years)

Treatment	Grade-wise yield of tubers (t ha^{-1})					Yield on dry weight basis (t ha^{-1})	
	0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
Levels of spacing							
A1	2.96	6.12	6.85	12.85	28.79	5.76	3.45
A2	3.72	7.18	8.60	9.56	29.05	5.81	3.49
$S.E_m$ (±)	**0.20**	**0.29**	**0.05**	**0.15**	**0.40**	**0.08**	**0.05**
CD(P=0.05)	NS	NS	0.30	0.65	NS	NS	NS
Levels of dates of haulm cutting							
B1	3.63	6.86	7.75	10.24	28.48	5.70	3.42
B2	3.05	6.45	7.69	12.18	29.36	5.87	3.52
$S.E_m$ (±)	**0.14**	**0.36**	**0.14**	**0.18**	**0.28**	**0.06**	**0.03**
CD(P=0.05)	0.54	NS	NS	0.68	NS	NS	NS
Levels of fertility							
C1	2.87	6.61	6.84	15.74	32.06	6.41	3.85
C2	3.17	6.29	8.04	10.87	28.37	5.68	3.41
C3	3.98	7.06	8.29	7.01	26.33	5.26	3.16
$S.E_m$ (±)	**0.14**	**0.33**	**0.32**	**0.25**	**0.57**	**0.11**	**0.07**
CD(P=0.05)	0.42	NS	0.96	0.74	1.70	0.34	0.21

TABLE 7. Interaction effect of spacing and fertility levels on grade wise and total tuber yield of potato (Pooled data of two years)

Treatment	Grade-wise yield of tubers (t ha^{-1})					Yield on dry weight basis (t ha^{-1})	
	0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
(A1C1)	2.53	6.42	6.41	18.30	33.65	6.73	4.04
(A2C1)	3.22	6.79	7.28	13.18	30.47	6.10	3.66
(A1C2)	2.81	5.65	6.99	12.47	27.91	5.58	3.35
(A2C2)	3.54	6.94	9.09	9.27	28.83	5.77	3.46
(A1C3)	3.55	6.31	7.15	7.80	24.80	4.96	2.98
(A2C3)	4.40	7.81	9.43	6.22	27.85	5.57	3.34
$S.E_m$ (±)	**0.20**	**0.47**	**0.45**	**0.35**	**0.80**	**0.16**	**0.10**
CD(P=0.05)	NS	NS	NS	1.05	2.40	0.48	0.29

TABLE 8. Interaction effect of spacing and dates of haulm cutting on grade wise and total tuber yield of potato (Pooled data of two years)

Treatment	Grade-wise yield of tubers (t ha^{-1})					Yield on dry weight basis (t ha^{-1})	
	0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
(A1B1)	3.34	6.29	6.90	11.80	28.34	5.67	3.40
(A2B1)	3.92	7.42	8.61	8.67	28.62	5.72	3.44
(A1B2)	2.58	5.96	6.79	13.91	29.24	5.85	3.51
(A2B2)	3.52	6.94	8.59	10.44	29.49	5.90	3.54
$S.E_m$ (±)	**0.19**	**0.50**	**0.20**	**0.25**	**0.40**	**0.08**	**0.05**
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS

consistently gave the lowest incidence of the disease. Highest early blight incidence (10.00%) and intensity (4.50%) was observed when spacing was 60cm X 10cm and fertilizer dose was 50% RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP. Minimum early blight incidence (3.50%) and intensity (2.25%) was recorded at a spacing of 60cm X 20cm and fertilizer dose 100% RDF of NPK+ 0.1% boric acid as foliar application. Decrease in early blight incidence with the increase in fertility levels was also confirmed by Mitra *et al.* (2014). No viral disease was observed during both the years. This may be due to intensive insecticide application since thirty days after planting of the crop.

Aphid incidence

The data recorded on aphid population clearly showed (Table 17) that no aphid infestation was found during the entire crop growth period in first year. What ever little population of aphids observed during the second year of experiment on 17th January was much below the critical level of aphid population (20 aphids/100 compound leaves) and was easily controlled by the prophylactic

Table 9. Interaction dates of haulm cutting and fertility levels on grade wise and total tuber yield of potato (Pooled data of two years)

Treatment	Grade-wise yield of tubers (t ha^{-1})					Yield on dry weight basis (t ha^{-1})	
	0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
(B1C1)	3.16	6.67	7.15	14.62	31.59	6.32	3.79
(B2C1)	2.59	6.54	6.54	16.87	32.54	6.51	3.91
(B1C2)	3.32	6.74	8.08	9.89	28.04	5.61	3.37
(B2C2)	3.03	5.85	7.99	11.85	28.71	5.74	3.45
(B1C3)	4.42	7.16	8.04	6.20	25.81	5.16	3.10
(B2C3)	3.54	6.95	8.54	7.81	26.84	5.37	3.22
S.E$_m$ (±)	**0.20**	**0.47**	**0.45**	**0.35**	**0.80**	**0.16**	**0.10**
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 10. Interaction effects of spacing, dates of haulm cutting and fertility levels on grade wise and total tuber yield of potato (Pooled data of two years)

Treatment	Grade-wise yield of tubers (t ha^{-1})					Yield on dry weight basis (t ha^{-1})	
	0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
(A1B1C1)	3.07	6.46	6.72	16.89	33.13	6.62	3.97
(A1B1C2)	3.04	6.19	7.00	11.27	27.51	5.50	3.30
(A1B1C3)	3.92	6.23	6.99	7.23	24.37	4.87	2.92
(A1B2C1)	1.99	6.39	6.10	19.70	34.17	6.83	4.10
(A1B2C2)	2.58	5.10	6.97	13.67	28.31	5.66	3.40
(A1B2C3)	3.19	6.38	7.31	8.36	25.23	5.05	3.03
(A2B1C1)	3.24	6.89	7.58	12.34	30.04	6.01	3.61
(A2B1C2)	3.60	7.29	9.15	8.51	28.56	5.71	3.43
(A2B1C3)	4.92	8.08	9.09	5.17	27.26	5.45	3.27
(A2B2C1)	3.20	6.69	6.98	14.03	30.90	6.18	3.71
(A2B2C2)	3.47	6.59	9.02	10.03	29.11	5.82	3.49
(A2B2C3)	3.89	7.53	9.76	7.26	28.45	5.69	3.41
S.E$_m$ (±)	**0.28**	**0.66**	**0.64**	**0.49**	**1.13**	**0.23**	**0.14**
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS

TABLE 11. Main effects of spacing, dates of haulm cutting and fertility levels on grade wise and total tuber number of potato (Pooled data of two years)

Treatment	Grade-wise number of tubers (nos. ha^{-1})				
	0-25g	25-50g	50-75g	>75g	Total
Levels of spacing					
A1	180093	161574	105093	96759	543518
A2	231019	200463	141204	85185	657870
$S.E_m$ (±)	**5792**	**4428**	**982**	**1823**	**9729**
CD(P=0.05)	35731	27321	6059	11245	60024
Levels of dates of haulm cutting					
B1	220833	189352	126389	86111	622685
B2	190278	172685	119907	95833	578704
$S.E_m$ (±)	**7768**	**7371**	**1669**	**1464**	**11871**
CD(P=0.05)	30327	NS	NS	5716	NS
Levels of fertility					
C1	171528	161806	102778	109722	545833
C2	206250	182639	127778	93056	609722
C3	238889	198611	138889	70139	646528
$S.E_m$ (±)	**6371**	**5720**	**5475**	**1985**	**11305**
CD(P=0.05)	19103	17149	16417	5950	33896

TABLE 12. Interaction effect of spacing and fertility levels on grade wise and total tuber number of potato (Pooled data of two years)

Treatment	Grade-wise number of tubers (nos. ha^{-1})				
	0-25g	25-50g	50-75g	>75g	Total
(A1C1)	144444	141667	90278	122222	498611
(A2C1)	198611	181945	115278	97222	593056
(A1C2)	187500	163889	106945	100000	558333
(A2C2)	225000	201389	148611	86111	661111
(A1C3)	208333	179167	118056	68056	573611
(A2C3)	269445	218056	159722	72222	719445
$S.E_m$ (±)	**9010**	**8089**	**7743**	**2807**	**15987**
CD(P=0.05)	NS	NS	NS	8415	NS

Table 13. Interaction effect of spacing and dates of haulm cutting on grade wise and total tuber number of potato (Pooled data of two years)

Treatment	Grade-wise number of tubers (nos. ha^{-1})				
	0-25g	25-50g	50-75g	>75g	Total
(A1B1)	194444	165741	108333	94445	562963
(A2B1)	247222	212963	144444	77778	682407
(A1B2)	165741	157408	101852	99074	524074
(A2B2)	214815	187963	137963	92593	633333
$S.E_m$ (±)	**10985**	**10424**	**2361**	**2070**	**16788**
CD(P=0.05)	NS	NS	NS	NS	NS

Table 14. Interaction dates of haulm cutting and fertility levels on grade wise and total tuber number of potato (Pooled data of two years)

Treatment	Grade-wise number of tubers (nos. ha^{-1})				
	0-25g	25-50g	50-75g	>75g	Total
(B1C1)	191667	168056	105556	101389	566667
(B2C1)	151389	155556	100000	118056	525000
(B1C2)	215278	190278	130556	91667	627778
(B2C2)	197222	175000	125000	94445	591667
(B1C3)	255556	209722	143056	65278	673611
(B2C3)	222222	187500	134722	75000	619445
$S.E_m$ (±)	**9010**	**8089**	**7743**	**2807**	**15987**
CD(P=0.05)	NS	NS	NS	NS	NS

measures taken and continuous roughing operation. Thus, there was no chance of viral disease transmission through aphids. In West Bengal dehaulming at 65 DAP was found to be safer so far as infestation and chances of viral disease transmission by the sucking pests are concerned as up to 10th January no aphid infestation was noticed in both the years of study.

Conclusion

Thus, from the present study it can be concluded that, for quality seed grade potato tuber production use of 60cm X 10cm spacing along with dehaulming at 65 days after planting, when planting is done on first week of November and grown with 50% RDF of NPK i.e. 100:75:75 kg N:P_2O_5:K_2O was found best under West Bengal situation to get higher numbers of quality seed grade sized potato tubers.

Acknowledgement

The authors are thankful to the Director of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, W.B. and All India Co-ordinated Research Project on Potato, Shimla, H.P. for valuable guidance, encouragement and financial support during the period of this research programme.

TABLE 15. Interaction effects of spacing, dates of haulm cutting and fertility levels on grade wise and total tuber number of potato (Pooled data of two years)

Treatment	Grade-wise number of tubers (nos. ha^{-1})				
	0-25g	25-50g	50-75g	>75g	Total
(A1B1C1)	169444	144445	94444	119445	527778
(A1B1C2)	197222	166667	108333	97222	569444
(A1B1C3)	216666	186111	122222	66667	591667
(A1B2C1)	119444	138889	86111	125000	469444
(A1B2C2)	177778	161111	105556	102778	547222
(A1B2C3)	200000	172222	113889	69445	555556
(A2B1C1)	213889	191667	116667	83333	605555
(A2B1C2)	233333	213889	152778	86111	686111
(A2B1C3)	294445	233333	163889	63889	755556
(A2B2C1)	183333	172222	113889	111111	580556
(A2B2C2)	216667	188889	144444	86111	636111
(A2B2C3)	244445	202778	155556	80555	683334
$S.E_m$ (±)	**12742**	**11439**	**10951**	**3969**	**22609**
CD(P=0.05)	NS	NS	NS	NS	NS

TABLE 16. Observation on disease incidence in the experimental field of potato (Mean data of two years)

Treatment	Phoma (%)		Early blight (%)		Late Blight (%)		Viral Disease
	Incidence	Intensity	Incidence	Intensity	Incidence	Intensity	
(A1B1C1)	8.35	2.00	3.50	2.25	0.00	0.00	0.00
(A1B1C2)	8.00	1.50	4.00	2.50	0.00	0.00	0.00
(A1B1C3)	7.25	1.50	4.50	2.50	0.00	0.00	0.00
(A1B2C1)	10.30	2.50	5.00	2.50	0.00	0.00	0.00
(A1B2C2)	7.45	2.00	6.00	3.00	0.00	0.00	0.00
(A1B2C3)	6.65	1.50	7.50	3.70	0.00	0.00	0.00
(A2B1C1)	11.50	2.80	5.50	3.00	0.00	0.00	0.00
(A2B1C2)	10.45	2.00	5.75	3.50	0.00	0.00	0.00
(A2B1C3)	10.00	1.50	6.25	3.50	0.00	0.00	0.00
(A2B2C1)	15.00	3.20	6.50	3.00	0.00	0.00	0.00
(A2B2C2)	10.00	3.00	10.00	4.00	0.00	0.00	0.00
(A2B2C3)	9.00	2.35	10.00	4.50	0.00	0.00	0.00

Table 17. Observation on aphid infestation in the experimental field of potato (Mean data of two years)

Treatment	Population of aphid per 100 compound leave					
	03.01.16	03.01.17	10.01.16	10.01.17	17.01.16	17.01.17
(A1B1C1)	0.00	0.00	0.00	0.00	-	-
(A1B1C2)	0.00	0.00	0.00	0.00	-	-
(A1B1C3)	0.00	0.00	0.00	0.00	-	-
(A1B2C1)	0.00	0.00	0.00	0.00	0.00	2.25
(A1B2C2)	0.00	0.00	0.00	0.00	0.00	2.00
(A1B2C3)	0.00	0.00	0.00	0.00	0.00	1.75
(A2B1C1)	0.00	0.00	0.00	0.00	-	-
(A2B1C2)	0.00	0.00	0.00	0.00	-	-
(A2B1C3)	0.00	0.00	0.00	0.00	-	-
(A2B2C1)	0.00	0.00	0.00	0.00	0.00	2.40
(A2B2C2)	0.00	0.00	0.00	0.00	0.00	2.15
(A2B2C3)	0.00	0.00	0.00	0.00	0.00	1.80

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 237-246, 2016

Influence on Yield of Aromatic Paddy cv. *Gobindobhog* by the Application of Biological Products of Tropical Agroeco-system

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Published : 30.10.2017

Abstract

A field experiment was conducted at the Block Seed Farm, Department of Agriculture, Govt. of West Bengal, Raina Block, Burdwan, West Bengal during the *Kharif* season, 2016 on aromatic rice cv. *Gobindobhog* to evaluate TAG NANO NPK (NANO NPK GLUCONATED GRANULAR FERTILIZER) in granular form. Eight treatments were used, where T_1 to T_6 Tag Nano NPK biofertilizer at 125, 100, 75, 50, '25 and 00 kg / ha of TAG NANO NPK Bio-fertilizer respectively in a descending order, conventional organic practice (T_7) and traditional chemicals (T_8) were included for comparison to each other. VAM – Nutrient Mobilizing Mycorrhizae, Granulated Organic Manure, effective Bio-pesticides, Bio-fungicide, Bio-insecticide, *Pseudomonas spp.*, *Trichoderma harzianum*, Super Spreader cum Penetrant and Plant Growth Promoter were applied in all treatments.

The results show that the lowest yield of paddy (2,758.62 kg / ha) was recorded under TAG NANO NPK @ '00' kg / ha (T_6) and was at par with Traditional Chemical Practice (T_8) [2,951.98 kg / ha] and significantly highest Yield was recorded under TAG NANO NPK Granular Form @ 100 kg / ha as basal (T_2) [3,854.32 kg / ha]. TAG NANO NPK a 125 kg / ha (T_1) [3,650.90 kg / ha], TAG NANO NPK 75 kg / ha (T_5) [3,640.25 kg / ha] were at par in between them and can be comparable with Conventional Organic Practice (T_7) [3,308.30 kg / ha]. The basal application of TAG NANO NPK Granular Form at 100 kg / ha in Aromatic Rice cv. *Gobindobhog* increased grain yield of 16.50, 30.56 and 39.71% over that of conventional organic (T_7), conventional chemical Practice (T_8) and TAG NANO NPK at 00 kg / ha (T_6) respectively.

Introduction

Fertilizers have an important role in enhancing food production and quality especially after the introduction of high-yielding and fertilizer responsive varieties. Most of the major crops grown such as rice requires Gobindobhog, a rice cultivar from West Bengal, India. It is a short grain, white, aromatic, sticky rice having a sweet buttery flavor. It derives its name from its usage as the principal ingredient in the preparation of the offerings to Govindajiu. Gobindobhog was traditionally cultivated in the District of Burdwan (Raina 1, Raina 2 and Khandokos), Midnapore (East and West), Hooghly, Nadia and Birbhum. The premium aromatic variety Gobindobhog rice is attracting more farmers in West Bengal. More farmers are taking up its cultivation since it gives higher productivity and remuneration per unit area.

Researches have been conducted to improve rice production but only a few can be seen in the literatures involving nano materials. (He, 2005; Liu *et al.*, 2007; Zhang *et al.*, 2007; Wang *et al.*, 2011; Gong and Dong, 2012; Sirisena *et al.*, 2013; Huang

et al., 2014). Nano Materials are defined as materials with a single unit between 1 and 100 nm in size in at least one dimension, hence, nano fertilizers are either Nano Materials which can supply one or more nutrients to the plants resulting in enhanced growth and yield, or those which facilitate for better performance of conventional fertilizers, without directly providing crops with nutrients (Liu and Lal, 2015). Some studies already proved the significance of nano fertilizers in some crops. Some beneficial effects include increase in nutrient use efficiency, better yield and reduced soil pollution (Naderi and Danesh-Sharaki, 2013). The potential contribution of Nano Fertilizers in improving growth and development of crops lies on its ability for greater absorbance and high reactivity. Nano Fertilizers can possibly enter the plant cells directly through the sieve-like cell wall structures if the particle sizes are smaller than the sizes of cell wall pores (5 - 20 nm).

India is the second biggest consumer of fertilizers in the world and it imports almost the entire supply of non-urea fertilizers. Tag Nano NPK is a comprehensive eco-friendly certified organic plant food. Tag Nano fertilizer was prepared by developing a methodology to use microbial enzymes for breakdown of the respective salts into nano-form and is 2 - 4 times less expensive compared to chemical fertilizers. It helps in reducing nutrient deficiency in plants increases the process of photosynthesis and promotes healthy growth.

Nano Fertilisers are more beneficial as compared to chemical fertilisers : (i) Three-times increase in Nutrient Use Efficiency (NUE); (ii) 80-100 times less requirement to chemical fertilisers; (iii) 10 times more stress tolerant by the crops; (iv) Complete bio-source, so eco-friendly; (v) 30% more nutrient mobilisation by the plants; (vi) 17 - 54 % improvement in the crop yield; (vii) Improvement in soil aggregation, moisture retention and carbon build up and (viii) there is no health hazard and is suitable for all crop varieties including food grains, vegetables and horticulture (Tarafdar, 2014).

The yield per hectare is also much higher than conventional fertilizers, thus giving higher returns to the farmers. Nano Fertilizer technology is very innovative but scantily reported in the literature. However, some of the reports and patents strongly suggest that there is a vast scope for the formulation of nano-fertilizers. Significant increase in yields have been observed due to foliar application of Nano particles as fertilizer (Tarafdar *et al.*, 2012; Banerjee, 2016; Rai, 2016).

However, information about the effects of the organic inputs particularly on scented rice in Gobindobhog is very limited in our country**.** This Gobindobhog variety is one of the choicable food for the world people which contains many nutrients including carbohydrates, proteins, dietary fiber, vitamins and minerals and biologically active phytochemicals and phenolic compounds (Tian *et al.*, 2005; Aguilar-Garcia *et al.*, 2007).

The present study was conducted to evaluate the effect of TAG NANO NPK (Gluconated Nano Fertilizer) in Granular Form on productivity of ***Kharif*** Aromatic Gobindobhog rice at Block Seed Farm, Department of Agriculture, Government of West Bengal, Raina, Burdwan, West Bengal.

Materials and Methods

A field experiment was conducted to study the Influence on yield of aromatic paddy cv. Gobindobhog by the application of full range of pure biological products of Tropical Agrosystem during the ***Kharif*** season of 2016 (July to December 2016) at Block Seed Farm, Government of West Bengal, Raina Block, District Burdwan, West Bengal, India. The experimental field was more or less uniform in topography and leveled with fair drainage condition. The soil was almost neutral in soil reaction (pH 6.7) and situated at 23^{o} 04' 12.00^{o} N Latitude and 87^{o} 52' 48.00^{o} E Longitude with an altitude of 13.4 metres above the mean sea level. The overall distribution of Monsoon rains during the cropping season was good. Rice variety used in this experiment was 'Gobindobhog' which was long duration variety of nearly 150 days from seed to seed during ***kharif*** season.

The experiment was laid out in a Randomised Block Design (RBD) with three replications. There

TABLE 1. Certified Organic Products of Tropical Agrosystem used in Rice Experiment on Gobindobhog Paddy.

TROPICAL'S PRODUCT	BIOLOGICAL TECHNICAL FORMULATION	DOSE / HA	TIME OF APPLICATION IN RICE
TAG BIONIK	VAM – Nutrient Mobilizing Mycorrhizae	10.0 Kg	Basal Application
NASA	Granulated Organic Manure	5.0 Kg Each	Basal & Top Dressing
TAG NANO NPK	Nano NPK Gluconated Granular Formulation	'0' Kg to '125' Kg 50 Kg	Dosage standardization at Basal Application As additional at Top Dressing
SUPER FAST GRANULE	Bio-insecticide	10 Kg	Control for Yellow Stem Borer at 15 DAT (Days After Transplantation)
TAG LIFE (H)	***Trichoderma harzianum*** (Bio-fungicide)	2.5 Kg	Sheath Blight At 45 DAT
TAG MONAS	***Pseudomonas spp.*** (Bio-fungicide)	2.5 Kg	Sheath Blight At 45 DAT
TAG POLY	Secondary Metabolites (Bio-fungicide)	0.5 Kg	Sheath Blight and Blast Control at 60 DAT
TAG COMBO	Secondary Metabolites (Bio-insecticide)	0.5 Kg	Green Leaf Hopper At 65 DAT
NANO CHARGER	Plant Growth Promoter	0.5 Litres (l)	Panicle Initiation Stage
TAG BUMPER	Plant Growth Promoter	1.5 l	15 days after Nano Charger Spray
TAG FOLDER	*Secondary Metabolites (Bio-insecticide)*	*2.0 l*	*Brown Plant Hopper*
TAG NOK	Secondary Metabolites (Bio-insecticide)	2.0 l	Brown Plant Hopper
KLOUD	Spreader cum Super Penetrant	0.25 ml / l of water or 125 ml	Mixed with any foliar sprayed products

Table 2. Organic Inputs applied as advised by Deptt. of Agric., Govt. of WB (T_7)

ORGANIC PRODUCTS	DOSAGE / HA	TIME OF APPLICATION
COW DUNG	3.0 MT	At the time of land preparation
VERMI-COMPOST (LOCAL)	500 Kg in one time	BASAL & TOP DRESSING
VAM FERTILILIZER	10 Kg in one time	BASAL & TOP DRESSING
MUSTARD CAKE	75 Kg each in one time	BASAL & TOP DRESSING
P - SOLUBILIZING	10 Kg	BASAL
BACTERIA (PSB)		
Trichoderma viride	2.5 Kg each [2 sprays] at an interval of 15 days	Sheath Blight Control
Pseudomonas spp.	2.5 Kg each [2 sprays at an interval of 15 days]	Control of Leaf, Node and Neck Blast
NEEM OIL	1.5 l each [2 sprays at an interval of 15 days]	Insect Pest control
Beauveria bassiania	2.5 Kg each [2 sprays at an interval of 15 days]	Brown Plant Hopper

were all together 8 nos. treatments with **TAG NANO NPK (Nano NPK Gluconated Granular Fertilizer).** Amongst the treatments (T_1 to T_6), **Tag Nano NPK** in granular formulation were applied in different doses @ '125' kg, '100' kg, '75' kg, '50' kg, '25' kg and '00' kg / ha as basal applications and rest of the agronomical practices like soil and crop management practices were made. The above treatments (T_1 to T_6) were compared with conventional organice (T_7) and traditional chemical practices (T_8) [inorganic fertilizers during basal and top dressing application and chemical pesticides for plant protection measures]. All those above treatments were applied as basal, topdressing and need based plant protection chemicals were also applied during the period of crop growth.

The following products were applied (T_1 to T_6) as per protocol sent from **M/s Tropical Agrosystem (India) Pvt. Ltd., Chennai** in this paddy experiment which were being certified by IMO, INDOCERT etc.

Harvesting of all the plots were made manually by sickle at their maturity to determine crop yield of all plots separately of the Experimental Field for comparing the effectiveness and accuracy of different doses of Tag Nano NPK applied in basal condition in the Gobindobhog Paddy in ***Kharif*** season, 2016.

Results and Discussions

(A) Plant Height :

The optimum planting geometry and basal application of TAG NANO NPK of different doses along with other organic inputs of M/s Tropical Agrosystem (I) Pvt. Ltd., Chennai in different stages of crop growth have exerted influence on plant height of aromatic rice cv. Gobindobhog during the year of experiment. It has been evidenced in Table No. 4 that the basal application of TAG NANO NPK in different doses had shown corresponding increase in plant height. The maximum plant height was recorded in all stages of crop growth under TAG NANO NPK @ 100 kg / ha (T_2) as basal application in rice over Conventional Organic Practice (T_7), Conventional Chemical Practice (T_8) and Untreated Control where no NANO NPK was applied (T_6). It was also noted that the highest dose of TAG NANO NPK @ 125 kg / ha (T_1) as basal in aromatic rice cv. Gobindobhog had exhibited a typical sigmoid pattern of growth in plant height in this experiment.

TABLE 3. Chemical applied at Block Seed Farm, Raina for Gobindobhog Rice (T_8)

PRODUCT	TECHNICAL	DOSAGE / HA	TIME OF APPLICATION
GROMOR (MIXED FERTILIZER)	**N:P:K** :: 10:26:26	125 Kg	Basal
ZINC SULPHATE	**Zn** Content 21%	12.5 Kg	Basal
UREA	Nitrogen 46%	50 Kg	Top Dressing
MURIATE OF POTASH	Potassium 60%	25 Kg	Top Dreesing
*HEXACON SUPER	5% SC	1.0 l	Appearance of Sheath Blight disease
*HEXACON	Hexaconazole 5% EC	1.0 l each 2 sprays at an interval of 15 days	Sheath Blight and Leaf Blast
*TEMPER	Tebuconazole 24.9% EW	0.5 l each 2 sprays at an interval of 15 days	Leaf and Neck Blast
*SUPER FAST GRANULE	Bio-insecticide	10 Kg	Control for Yellow Stem Borer at 15 DAT
*ACTION 505	Chlorpyrifos 50% + Cypermethrin 5%	0.75 l 2 sprays at an interval of 15 days	Leaf Folder and Green Leaf Hopper
*BANNERR	Bifenthrin 10% EC	0.5 l 2 sprays at an interval of 15 days	Leaf Folder and Green Leaf Hoppers
TAG FOLDER	Secondary Metabolites (Bio-insecticide)	2.01 2 sprays at an interval of 15 days	Brown Plant Hopper
*TAG BUMPER	Plant Growth Promoter	1.5 l each 2 sprays at an interval of 15 days	Yield Enhancer
TOKEN	Dinotefuran 20% SG	0.15 l 2 sprays at an interval of 15 days	Brown Plant Hopper

*** Chemical Products were applied on Gobindobhog Paddy Experimental Plot (T_8) supplied by M/s Tropical Agrosystem (I) Pvt. Ltd., Chennai.**

Table 4. Height of plant at different stages of cropping cycle

TREATMENTS (KG / HA)	PLANT HEIGHT (CM) 21 DAT	60 DAT	90 DAT
T_1 NANO NPK '125'	45.21	70.51	125.86
T_2 NANO NPK '100'	50.50	83.43	157.35
T_3 NANO NPK '75'	46.59	79.51	135.21
T_4 NANO NPK '50'	47.35	70.84	135.25
T_5 NANO NPK '25'	44.12	71.23	130.44
T_6 NANO NPK '00'	40.56	60.53	120.48
T_7 CONVENTIONAL ORGANICPRACTICE	46.35	80.54	145.49
T_8 CONVENTIONAL CHEMICAL PRACTICE	40.83	68.84	110.25
CC.D. AT 5% LEVEL	**3.22**	**5.73**	**10.98**

Table 5. Numbers of tillers of Gobindobhog at different stages of cropping cycle

TREATMENTS (KG / HA)	NUMBERS OF TILLERS (CM) 30 DAT	60 DAT	90 DAT
T_1 NANO NPK '125'	17.25	25.54	18.50
T_2 NANO NPK '100'	19.88	33.37	25.39
T_3 NANO NPK '75'	15.34	25.97	21.20
T_4 NANO NPK '50'	15.55	24.54	21.28
T_5 NANO NPK '25'	12.80	19.38	16.32
T_6 NANO NPK '00'	10.58	15.28	13.36
T_7 CONVENTIONAL ORGANIC PRACTICE	17.40	30.34	24.14
T_8 CONVENTIONAL CHEMICAL PRACTICE	9.55	20.90	18.88
CC.D. AT 5% LEVEL	**2.47**	**4.43**	**4.20**

(B) Number of Tillers :

It has been revealed from the Table No. 5 that the numbers of tillers were found maximum in all stages of growth under Tag NANO NPK applied @ 100 kg / ha as basal (T_2) in the present study on Gobindobhog rice which was at par with Conventional Organic Practice (T_7). Lowest yield was observed under Untreated Control where no TAG NANO NPK was applied as basal (T_6). The figure indicates in TAG NANO NPK '00' kg / ha (T_6) that during seedling or tillering stage, the crop plant requires adequate primary nutrients for its growth and development but due to absence of initial nutrients under T_6, the crop showed the unhealthy symptoms which has already been reflected to its entire cropping cycle. But all the organic inputs written in Table No. 1 were applied afterwards in T_6 which did not recovered in later stages of cropping cycle due to short fall of primary nutrients during the early seedling stage. Numbers of tillers counts at 90 DAT (Days After Transplantation) can be considered as Effective Tillers as Gobindobhog variety is long duration crop nearly 150 days from seeds to seeds. The number of tillers of Conventional Chemical Practice (T_8) was significantly less as compared to Conventional Organic Practice (T_7) as well as TAG NANO NPK in all treatments except T_6.

(C) Yield Attributing Characters :

(a) Numbers of Grains per Panicle :

It has been recorded in Table No. 6 that the number of grains per panicle was significantly higher under TAG NANO NPK @ 100 kg / ha (T_2) and was at par with conventional organic practice (T_7) over untreated control (T_6) and were observed to have the same trends in the following orders :

TAG NANO NPK @ '100' kg / ha (T_2) > TAG NANO NPK @ '125' kg / ha (T_1) > TAG NANO NPK @ '75' kg / ha (T_3) > TAG NANO NPK @ '50' kg / ha (T_4) > Conventional Organic Practice (T_7) > TAG NANO NPK @ '25' kg / ha (T_5) > Conventional Chemical Practice (T_8) > TAG NANO NPK @ '00' kg / ha (T_6). It has been found that beyond TAG NANO NPK @ 100 kg / ha showed the less yield of rice under TAG NANO NPK @ 125 kg / ha (T_1) which followed the sigmoid curve ('S' shaped curve) when growth is plotted against time in this experiment.

(b) Numbers of Filled Grains per Panicle :

The experimental data reveal in Table No. 6 that the numbers of filled grains per panicle had shown the same trend as observed in the heading under **Results and Discussion** of **Numbers of Grains per panicle**. TAG NANO NPK @ 100 kg / ha (T_2) had shown its superiority over all treatments and was at par with conventional chemical practice (T_7). TAG NANO NPK @ 00 kg / ha (T_6) had recorded lowest numbers of filled grains / panicle and was at par with conventional chemical practice (T_8).

© Test Weight :

Test Weight of 1,000 grains of rice cv. Gobindobhog is an important yield component which contributes towards its final yield. Rice grains were collected from each treatments and found significant variations amongst the treatments. The highest and lowest test weights were recorded under TAG NANO NPK @ 100 kg / ha as basal application (T_2) [14.53 g] and TAG NANO NPK @ 00 kg / ha (T_6) [13.06 g] respectively. The data (Table No. 6) shows that there is a general trend of increase in test weight corresponding to higher TAG NANO NPK application. It indicates the influence of TAG NANO NPK as basal in Gobindobhog rice in ***Kharif*** season and had shown the same trend as observed in other parameters in this experiment (Table No. 6).

(D) Grain Yield of Rice / ha :

Effect of TAG NANO NPK in different doses applied as basal were significantly influenced the grain yield of rice cv. Gobindobhog in ***Kharif*** season, 2016. TAG NANO NPK GRANULAR FORMULATION broadcasted before transplanting in Gobindobhog rice for an uniform distribution over the entire field and to mix it thoroughly with the soil. The statistically analysed data presented in Table No. 6 indicate that the yield of rice grain cv. Gobindobhog has been significantly affected on the variable dosage of TAG NANO NPK applied as basal besides other agronomic practices are of paramount importance in Gobindobhog

Table 6. Yield Attributing Characters of Gobindobhog Rice at Harvest

TREATMENTS (KG / HA)	NOS. OF GRAINS PER PANICLE	NOS. OF FILLED GRAINS PER PANICLE	TEST WEIGHT (GRAM)	YIELD / HA (KG)	INCREASE OR DECREASE OVER T_8 (+ / -)	INCREASE OR OR DECREASE OVER T_6 (+ / -)
T_1 NANO NPK '125'	170.38	165.21	14.20	3,650.40	(+) 23,65	(+) 32.33
T_2 NANO NPK '100'	180.42	177.68	14. 53	3,854.32	(+) 30.56	(+) 39.71
T_3 NANO NPK '75'	165.47	160.87	14.41	3,640.25	(+) 23.31	(+) 31.96
T_4 NANO NPK '50'	160.58	158.43	14.19	3,319.00	(+) 12.43	(+) 20.31
T_5 NANO NPK '25'	150.28	148.34	14.37	3,244.05	(+) 9.89	(+) 17.60
T_6 NANO NPK '00'	145.72	140.50	13.06	2,758.62	(-) 6.55	—
T_7 CONVENTIONAL ORGANIC PRACTICE	175.70	170.68	14.28	3,308.30	(+) 12.07	(+) 19.93
T_8 CONVENTIONAL CHEMICAL PRACTICE	150.17	147.16	14.09	2,951.98	—	(+) 07.00

rice. The highest yield was obtained under TAG NANO NPK @ 100 kg / ha (T_2) [3,854.32 kg / ha], Conventional Organic Practice (T_7) [3,308 kg / ha], Conventional Chemical Practice (T_8) [2,952 kg / ha] and TAG NANO NPK @ '00' kg / ha (T_6) [2,758 kg / ha] in Gobindobhog rice. It has been estimated that there was an increase of 30.56 % and 39.71% grain yield under TAG NANO NPK @ 100 kg / ha [3,854.32 kg / ha] over Conventional Chemical Practice (T_8) and TAG NANO NPK @ '00' kg / ha (T_6) respectively. TAG NANO NPK @ 125 kg / ha had shown second highest yield and showed a sigmoid trend of yield in this experiment. It has been revealed from the Table No. 6, that under the optimum dose of TAG NANO NPK @ 100 kg / ha (T_2), the maximum grain yield of rice cv. Gobindobhog can be obtained amongst the treatments scheduled in this experiment.

The Nano Fertilizer (TAG NANO NPK in Granular Form) used in this experiment is a formulated colloidal farming fertilization supplement that facilitates nutrient uptake, transportation and absorption. As shown in Table No. 4, the TAG NANO NPK at high to low doses as basal significantly increased the plant height over the control. In addition, plant height was more when Nano Fertilizer was applied at a lower application rate. These suggest that Nano Fertilizer can either provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth. Related study by Liu and Lal (2014) revealed similar findings in soybean. Nano Fertilizer may have affected these processes through its transportation capabilities in terms of penetration and movements within the plant systems. Table No. 4, Table No. 5 and Table No. 6 were found significant effect of TAG NANO NPK @ 100 kg / ha as basal over untreated control on plant height, numbers of tillers as well as reproductive tillers and total number of grains / panicles, numbers of filled grains / panicle and yield / ha. Application of Nano Fertilizer at the basal stage of rice was only supplemental. Nonetheless, it was evident that Nano Fertilizer application enhanced the above mentioned parameters, secondary metabolites

produced by plants throughout their development for several reasons: defense against microorganisms, insects, or herbivores (Crozier et al., 2006; Herms and Mattson, 1992); nutrient availability (Herms and Mattson, 1992); exposure to ultra-violet radiation (Rozema *et al.*, 1997); and allelopathic interactions (Mann, 1987).

Conclusions

Application of nanotechnology in agriculture is still in its budding stage. However, it has the potential to revolutionize agricultural systems particularly where the issues on fertilizer applications are concerned. Nano Fertilizer application promoted the growth, development, total Polyphenol Content and antioxidant activity in rice and has the potential to improve crop production and plant nutrition. **TAG NANO NPK Granular Form @ 100 kg / ha as basal manufactured by M/s Tropical Agrosystem (I) Pvt. Ltd., Chennai along with the normal package of practice for getting 16 – 40 % more grain yield as compared to Conventional Organic Practice and Traditional Chemical Farming in aromatic rice cv. *Gobindobhog* in *kharif* season.** The outcome of this research would be beneficial for further studies involving the application of Nano Technology in the field of agriculture.

Acknowledgementa

Thanks are due to **O.S.D & Ex-Officio, Director of Agriculture, Government of West Bengal**, Jessop Building, 63, N.S. Road, Kolkata 700001; **Chief Advisor to Chief Minister, Govt. of West Bengal; DDA / CDP; DDA (Admin.), Burdwan; ADA (Admin.), Burdwan; for giving the permission to organize this Organic Project in Raina Farm, Burdwan, West Bengal, India** and the authors had taken the valuable advise/s from time to time from most of the Dignitaries / Officers of Agricultural Departments, Government of West Bengal, Jessop Building for conducting this organic project successful.

The authors are thankfully acknowledged **Mr. Soumen Roy, Assistant Director of Agriculture, Raina Block, Burdwan** for his kind presence during the time of observations and his heartful cooperation for providing all kinds of facilities in Block Seed Farm, Raina, Burdwan for organizing this organic project successful in the kharif season, 2016.

The authors are happy to acknowledge **M/s Tropical Agrosystem (I) Pvt. Ltd., Chennai** for providing all **Government Certified Organic Products** in this Organic Project on **Gobindobhog rice** in Block Seed Farm, Government of West Bengal, Raina, Burdwan, West Bengal in the ***kharif*** season, 2016.

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Indian Agriculturist, Vol. 60, No. 3 & 4, pp. 247-254, 2016

Genetic Implication of Quantitative Traits and Their Interrelationship With Seed Yield in Mungbean (*Vigna Radiata* L. Wilczek)

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Published : 30.10.2017

Abstract

Mungbean is one of the most important pulse crops to meet the challenges of food and nutritional security due to its high protein supplement in subtropical zones of the world. Keeping this in mind, the present study was conducted to assess the genetic parameters on eight quantitative traits among forty two mungbean genotypes. The analysis of variance revealed highly significant difference for all traits that indicating these characters would be best for phenotypic selection. High GCV and high PCV for seed yield per plant (50.80, 52.26) were estimated. PCV value was higher than GCV value that indicating less environmental effect of all traits. High heritability coupled with genetic advance as percent of mean value were shown for seed yield per plant (95%, 31.81) harvest index, plant height, seeds per pod, pods per plant, suggested that these traits were regulated by additive gene action. Assessment of correlation revealed that seed yield had positive significant correlation with branches per plant, pods per plant, pod length, seeds per pod and branches per plant. Result shown genotypic correlation was higher than phenotypic correlation indicating strong association between traits. Path coefficient analysis indicated that the traits number of branches per plant, seeds per pod, harvest index and pod length had high positive direct effect on seed yield. The residual effect (0.59), indicating that contribution of inherent character was low. Hence, the present finding suggests that more emphasis should be given on traits while executing selection for genetic enhancement of seed yield in mungbean.

Key words : Mungbean, genetic parameters, correlation, path, yield.

Introduction

The world population is increasing at an alarming rate and obviously overwhelming majority of this populous world is suffering due to insufficient and imbalanced diet. The plant scientists are facing the challenges how to meet the food requirement of this unchecked population **(Thirtle *et al*., 2003).** In this acute context, pulses are excellent option of dietary protein. Mungbean (*Vigna radiata* L. Wilczek), when used as food with other cereals they definitely meet the requirement of a balanced diet. In spite of its importance as food and feed, very little attention has been paid to its quantitative and qualitative improvement in the country. Mungbean is an excellent source of easily digestible protein of low flatulence, which complements the cereal-based diet of the Asian people **(Muhammad *et al*., 2001)** and rich in essential amino acid particularly in lysine which is deficient in most of the cereals **(Degefa *et al*., 2014)**. Besides providing protein in the diet, mungbean has the remarkable quality of helping the symbiotic root rhizobia to fix atmospheric nitrogen and hence to enrich soil fertility **(Mondal *et al*., 2012)**. In India it is grown in prekharip/kharif (spring/ summer) (East India, North India) and rabi season (South India). India alone with an area of 3.42 million hectare and production of 1.70 million tonnes accounts for about two third of global production **(Kular 2014 and Sinha *et al*., 2013)**. Seed yield is a complex quantitative character, difficult to select directly and associated with various contributing characters which controlled by polygene and also

environmental effect. While substantial yield improvements have been made, mungbean yields are still low which has restricted its wider use as an alternative pulse crop in Asian farming systems **(Lambrides *et al*., 2007)**. To accomplish this, crop improvement should aim at broadening the genetic base of the breeding stock **(Suresh** et al**., 2010)**. Knowledge of relationship among yield and yield attributing traits is a prerequisite for an efficient plant breeding program. Proper evaluation of the extent of genetic variation available for yield components, heritability and genetic advance could be of great help for the breeders in order to choose good genotypes for improvement **(Hafiz *et al*.,2014)**. Genetic parameters provide an indication of comparative significance of the different types of gene effecting on the entire variation of traits **(Degefa *et al*., 2014)**. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) showed a wide spectrum of variability in most of the traits **(Suresh *et al*., 2010)**. Estimation of correlation provides total or net effect of the segregating genes where some of the genes may increase both the traits causing positive correlation and on the other hand may decrease the traits causing negative correlation **(Singh *et al*., 2014)**. Path co-efficient analysis is essential to analyze the cause and effect relationship between dependent and independent variable to entangle the nature of relationship between the variable by their means. This could be helped to the improvement of yield through indirect selection **(Rohman *et al*., 2003**). Therefore, the current study was evaluated to the genetic variation for quantitative desired traits in mungbean which will be beneficial for the selection of high yielding genotypes to use them in the next breeding program.

Materials and Methods

The present study was carried out at the Department of Genetics and Plant Breeding at Institute of Agricultural Science, University of Calcutta. The experimental material consisted of forty two mungbean genotypes was evaluated at University of Calcutta's experimental farm, Baruipur, District of South 24 Parganas during the period of March 2015 to May 2015. The experiment was laid out in a Random Block Design (RBD) using three replications with experimental plot. There were rows per plot of each genotypes spaced 30 cm apart. Length of each row was 3 m, with plant to plant distance of 3 cm within a row. Experimental field was prepared by ploughing and followed by laddering. Then, the stubble and uprooted weeds were removed from the field. After final land preparation, seeds were shown on March 15, 2015. Five randomly selected healthy plants were harvested from replication and each genotype when the colour of pod becomes black or brown. Pods of each plant were kept separately in envelop and dried. Threshing was done by hand and strict care was taken to avoid mixture of seeds. Data on different parameters like plant height, branches per plant, pods per plant, pod length, seeds per pod, 100 seed weight, harvest index and seed yield per plant were recorded from each replication. The data obtained were statistically analyzed by SPAR 2.0 software. Analysis of variance (ANOVA), co-efficient of variability, broad sense of heritability, and genetic advance were worked out according to the method of **Johnson et al. (1955)**. Pearson's correlation coefficients were calculated to determine the relationships between yield and yield components. Path coefficient analysis was used as determined by **Dewey and Lu (1959)** to partition the correlation coefficients and to determine the direct and indirect effects.

Results and Discussion

The natural variability for yield and yield related traits is very narrow in highly self-pollinated mungbean crop and genetic parameters provide an indication of the relative importance of the various types of gene effects affecting the total variation of plant character **(Degefa et al., 2014)**

3.1. Analysis of Variance (ANOVA):

Variation refers to observable differences among individuals for a particular trait. The data collected on different traits were analyzed and presented in **Table 1.** Analysis of variance (ANOVA) showed significant variation for plant height, pod length, number of seeds per pod, number of pods per plant, 100 seed weight, harvest index, and seed yield per plant.

TABLE 1. Analysis of variance (ANOVA) for eight quantitative traits in mungbean.

S.O.V	Plant height	Branch/plant	Pods/plant	Pod length	Seeds /pod	100 seeds wt	Harvest index	Seed yield /plant
MS(V)	169.28**	1.17	116.67**	2.01**	10.52**	1.91**	69.44**	26.18**
MS(R)	40.36**	0.04	39.33**	1.94	0.63	3.25*	1.13	3.66*
MS(E)	26.96	0.18	14.46	0.42	0.25	0.16	3.50	0.49

** Denotes 1% level Of Significance,* Denotes 5% Level Of Significance.
SOV= Source of Variation. MS(R) = Replication Mean Sum Of Square,
MS(V)=Variety Mean Sum Of Square, MS(E) = Error Mean Sum Of Square.

But only branches per plant were not significant. This clearly indicates the presence of considerable variability among the forty two genotypes of mungbean used in the present investigation for all the characters studied and provides an opportunity for further analysis and estimation of parameters of variability.

Genetic Parameters

The Genotypic and Phenotypic Variance and their Coefficient of Variation (GCV and PCV), heritability (H%), Genetic Advance (GA) and Genetic Advance % of Mean (GA% of Mean) expressed as percentage of means of the above mentioned traits of the forty two mungbean genotypes have been presented in **TABLE 2.**

The estimates of GCV and PCV revealed that GCV was less than its corresponding estimates of PCV for seed yield and its related traits. The GCV was estimated to be high for seed yield per plant (**50.80),** harvest index (**25.74)**, pods per plant (**25.29)**, 100 seed weight (**20.04)**, and seeds per pod (**16.38).** But branches per plant (**15.42)** and plant height (**14.85)** were estimated lower values while pod length (**9.62)** was shown lowest value. This indicates a wide variability in GCV values and it helps to measure the range of genetic variability present in the quantitative traits. The PCV was estimated to be also high for seed yield (**52.26)**, pods per plant (**30.18),** harvest index (**27.71),** 100 seed weight (**22.60)**, and branches per plant (**19.24).** The PCV values again showed a similar trend for the above mentioned traits except branches per plant. The high GCV and PCV values demonstrate the presence of sufficient inherent genetic variability over which selection can be more effective. The PCV value was found higher than the GCV for all traits and the difference between them were very small that indicates less environmental influence on those characters except for number of branches per plant where the environment had its own contribution on the performance of the traits in addition to genotypic variance.

Heritability is a measure of the value of selection for particular character and also as an index of transmissibility of a character whereas genetic advances are indicative of the expected genetic progress for a particular trait under suitable selection produce **(Koul *et al*., 1997).** Estimate of broad sense heritability in this study ranged from **Pod length (56%), Plant Height (64%)**, **Branches per Plant (64%), Pods per Plant (70%)**, **100 Seed weight (79%), Harvest Index (86%), Seeds per Pod (93%)** and **Seed Yield per Plant (95%).** Generally, moderately high heritability was coupled with relatively high genetic coefficient of variation for almost all traits except pod per plant (Ref 15). Traits having highest phenotypic heritability value which is close to 1 show a good index of genotypic merit, so genetic gain can be made easily through selection **(Johnson and Frey, 1967; Adhikari and Pandey, 1982; Degefa *et al*., 2014).** Among all the traits, **seed yield per plant (95%)** shown highest heritability. Similarly, **seeds per pod (93%)** show high heritability that was due to additive gene effect and **pod length (56%)** shows lowest heritability among all characters.

Table 2. Estimates of genetic parameters for eight quantitative traits in mungbean genotypes.

Parameter	Plant Height	Branches/ Plant	Pods/ Plant	Pod Length	Seeds/ Pod	100 Seed Weight	Harvest Index	Seed Yeild/ Plant
GCV	14.85	15.42	25.29	9.62	16.38	20.04	25.74	50.80
PCV	18.59	19.24	30.18	12.90	16.96	22.60	27.71	52.26
H%	0.64	0.64	0.70	0.56	0.93	0.79	0.86	0.95
GA	9.05	0.76	8.44	0.83	3.56	1.24	8.33	5.70
GA % OF Mean	6.52	6.78	11.87	3.62	10.17	10.93	15.46	31.81

GCV = Genotypic co-efficient of variance.

PCV = Phenotypic co-efficient of variance.

H%= Heritability percentage.

GA= Genetic Advance.

GA% of Mean= Genetic Advance percentage of Mean.

Estimation of genetic advance indicates the mode of gene action involved in the expression of various polygenic traits. In the present study high genetic advance was obtained for plant height (**9.05**), pods per plant (**8.44**), harvest index (**8.33**) and seed yield per plant (**5.70**). Relatively low genetic advance was observed for seeds per pod (**3.56**), 100 seed weight (**1.24**), pod length (**0.83**) and branches per plant (**0.76**). The highest genetic advance trait was observed for plant height (**9.05**) and lowest trait was observed for branches per plant (**0.76**). The high genetic advance indicates that the traits were controlled by additive genes which can easily be transferred to next generation. The low genetic advance is understood to be non-additive gene action which can be expressed as epistatic or dominance effect **(Hafiz *et al.*, 2014; Degefa *et al.*, 2014).**

The highest genetic advance as percent of mean (GA% Mean) was recorded for seed yield per plant (**31.81**). Other traits of genetic advance as percent of mean were observed from Pod length (**3.65**), plant height (**6.52**), branches per plant (**6.78**), seeds per pod (**10.17**), 100 seed weight (**10.93**), pods per plant (**11.87**) and harvest index (**15.4).** Estimation of heritability and genetic advance as percentage mean considered together will no doubt help in drawing conclusion about the nature of gene action governing a particular character. Due to the fact that combined study of heritability and genetic advance is more reliable in predicting the effect of selection **(Johnson *et al.*, 1955; Idahosa *et al.*, 2010)**.

So, these genetic parameters are suggesting that these traits manifest under the control of additive gene action and therefore, the possibility of improvement of these traits exists through simple selection.

Association Studies

Correlation:

The correlation coefficient which provides symmetrical measurement of degree of association between variables or characters helps us in understanding the nature and magnitude of association among yield and yield attributing traits **(Dalbeer *et al.*, 2013)**. The genotypic correlation (r_g) and phenotypic correlation (r_p) were presented in Table **3**.

Genotypic correlation (r_g) :

Through genotypic correlation, seed yield per plant shown positive correlation with branches per plant, pods per plant, pod length and seeds per pod. Except pods per plant, other three traits show both 5% level (pod length 0.321*, seeds per pod 0.380*) and 1% level of significance (branches per plant

TABLE 3. Genotypic (r_g) and phenotypic (r_p) correlation coefficients among quantitative traits in mungbean

Traits		Plant height (cm)	Branches /Plant	Pods /Plant	Pod length (cm)	Seeds /Pod	100 seed weight (gm)	Harvest index	Seed yield/ Plant (gm)
Plant height (cm)	r_g	1.00	0.279	0.061	-0.173	0.232	-0.237	0.145	-0.097
	r_p		0.141	0.077	-0.165	0.066	-0.188	0.152	-0.087
Branches/ Plant	r_g			0.209	-0.201	-0.146	0.328*	0.219	0.588**
	r_p		1.00	0.174	-0.051	0.064	0.102	0.073	0.267
Pods/ Plant	r_g			1.00	0.061	0.406**	0.033	0.164	0.253
	r_p				0.061	0.295	0.046	0.105	0.186
Pod length (cm)	r_g				1.00	-0.035	0.339*	0.111	0.321*
	r_p					0.012	0.158	0.096	0162
Seeds/ Pod	r_g					1.00	-0.360*	0.294	0.380*
	r_p						-0.156	0.118	0.031
100 seed weight (gm)	r_g							0.113	-0.218
	r_p						1.00	0.053	0.342*
Harvest index	r_g							1.00	-0.218
	r_p								-0.210
Seed yield/ Plant (gm)	r_g								
	r_p								1.00

**** Denotes 1% level Of Significance,* Denotes 5% Level Of Significance.**

TABLE 4. Direct and indirect effects of ten characters on seed yield per plant in mungbean

Traits	**Plant height (cm)**	**Branches/ Plant**	**Pods/ Plant**	**Pod length (cm)**	**Seeds/ Pod**	**100 Seed weight (gm)**	**Harvest Index**
Plant height (cm)	**-0.308**	0.231	-0.002	-0.079	0.062	0.004	-0.005
Branches/ Plant	-0.086	**0.826**	-0.006	-0.091	-0.039	-0.005	-0.009
Pods/Plant	-0.018	0.173	**-0.031**	0.028	0.109	-0.001	-0.007
Pod length (cm)	0.054	-0.166	-0.010	**0.456**	-0.010	-0.006	-0.005
Seeds/Pod	-0.072	-0.121	-0.013	-0.016	**0.267**	0.006	-0.012
100 Seed weight(gm)	0.073	0.271	-0.001	0.155	-0.096	**-0.017**	-0.005
Harvest Index	0.045	-0.181	0.005	-0.051	-0.079	0.002	**0.040**

0.588**). Seed yield also shown negative genotypic correlation with plant height (-0.097), 100 seed weight (-0.218), harvest index (-0.218).

Plant height observes positive correlation with branches per plant, pods per plant, seeds per pod, harvest index and negative correlation with pod length and 100 seed weight. But here branches per plant shows positive correlation with pods per plant, harvest index, 100 seed weight, and seed yield per plant and negative correlation with pod length and seeds per pods. Among all the traits, 100 seed weight and seed yield per plant show high significant correlation. The 100 seed weight shown 5% level of positive genotypic significance (0.328*). Pod per plant shown positive correlation with all traits but only with seeds per pod shown 1% level of highly positive genotypic significant correlation (0.406**). Pod length shows positive correlation with 100 seed weight, harvest index and negative correlation only with seeds per pod. But only with 100 seed weight shown 5% level of significant positive genotypic correlation (0.339*). Seeds per pod show positive correlation with harvest index, seed yield per plant and negative correlation only with 100 seed weight. Among all traits, only 100 seed weight (-0.360*) shows 5% level of negatively significant correlation. The 100 seed weight shows positive correlation with harvest index. No traits are shown to have significant correlation with 100 seed weight. Harvest index shows negative correlation with seed yield per plant. These findings are broadly in agreement with some of the earlier reports (**Singh. 1987; Bhadra *et al.* 1987).**

Phenotypic correlation (r_p) :

The phenotypic correlation coefficients were generally lower than genotypic correlation coefficients for most of the traits. Seed yield per plant shown positive correlation with branches per plant, pods per plant, pod length, seeds per pod and 100 seed weight and negative correlation with plant height and harvest index. Among all the traits, only 100 seed weight (0.342*) shows 5% level of significant phenotypic correlation with seed yield per plant. Plant height shows positive phenotypic correlation with branches per plant, pods per plant, seeds per pod, and harvest index and negative correlation with pod length and 100 seed weight. Branches per plant is shown positively correlated with pods per plant, seeds per pod, 100 seed weight, harvest index, and seed yield per plant and is shown negatively correlated with pod length. Although the pods per plant is shown positively correlated with all traits but they are not significant. Similarly the pod length also shows positive correlation with all characters but not significant with any traits. Seeds per pod shows positive correlation with harvest index and negative correlation with 100 seed weight but again not significant. The 100 seed weight shows positive correlation with harvest index but not significant. Harvest index shows negative correlation with seed yield per plant. These findings are broadly in agreement with some of the earlier reports **(Rohman et al., 2003; Dalbeer et al., 2013)**

Hence, the breeding point views this situation as favourable because selection for one trait may bring correlated response for improvement of other traits which are positively associated with the relationship.

Path Co-efficient Analysis:

Path analysis is biometrical tools for getting information regarding cause and effect of independent variables (yield) on the dependent (component) variable to provide clearer picture among eight traits association for formulating efficient selection strategy **(Gul *et al.*, 2007)**.

Path coefficient analysis is a tool to partition the observed correlation coefficient into direct and indirect effects of independent variables (yield) on the dependent (component) variable to provide clearer picture of character associations for formulating efficient selection strategy.

(Gul *et al.*, 2007). Path analysis has emerged as a powerful and widely used technique for understanding the direct and indirect effect of contributing traits **(Dalbeer *et al.*, 2013)**. In this present study, path coefficient analysis was carried out using simple correlation among eight quantitative traits (**Table 4**). Highest positive effect on seed yield per plant exerted by branches per plant **(0.826**) and pod length **(0.456)** whereas plant height **(-0.308)**, pods per plant (**-0.031)**, 100 seed weight **(-0.017)** have

substantial negative direct effects on seed yield per plant. However, other characters that were contributing substantially positive direct effect on seed yield were shown seeds per pod **(0.267)** and harvest index **(0.040)**. Branches per plant **(-0.181)** and plant height **(-0.086)** showed negative indirect effects on seed yield per plant. The remaining estimates of the indirect effects in the analysis were too low to be considered important. Branches per plant (0.271), pod length (0.155), seeds per pod (0.109) were shown to have positive indirect effect on seed yield via pods per plant and 100 seed weight. The result of residual effect (0.59) revealed that the variables studied in the present investigation explained only 41% of the variability in the yield and the other attributes besides the traits studied are contributing for seed yield per plant **(Srivastava and Singh, 2012)**. The traits mentioned above should be given due consideration at the time of formulating selection program in mungbean.

Conclusion:

In any crop improvement program association of high yielding varieties with quantitative traits is necessary. Success of the crop improvement generally depends on magnitude of genetic variability and heritability. From the present study, traits with high heritability values can therefore be easily selected as the effective strategy in improving these traits as well as the yield. From correlation among traits are shown like a pleiotropy, linkage or physiological associations among characters. The linkage is a cause of transit correlations particularly in a population derived from crosses between divergent strains. Path coefficient analysis indicated that the traits number of branches per plant, seeds per pod, harvest index and pod length had high positive direct effect on seed yield and indirect traits had high heritability along with significant correlation with yield. In the present investigation the genotypes with high values of these characters have been identified and that would be utilized in breeding programmes aimed at development of high yielding varieties.

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