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Evaluation of Allelopathic Potential of *Adhatoda Vasica* by Physio-Biochemical Approaches

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Abstract

An experiment was designed to evaluate the allelopathic potential of a gregariously growing medicinal herb *Adhatoda vasica*. Our preliminary observation that in the area of *Adhatoda vasica* growing soil, other plant species are often out competed and thus *Adhatoda* often makes mono-specific stand by not allowing the other plants to grow normally. This observation of dominance of *Adhatoda* was critically studied from physio-biochemical view point and thus existence of allelopathic property of this vigorously growing species was established by analysing a number of allelopathy indicating parameters.

This paper deals with the evaluation of allelopathic potential of *Adhatoda vasica* which was justified by analysing some reliable indices of allelopathy like seed germination behaviour, measured in terms of percentage, speed and T_{50} values (time required for 50% germination) of germination, leaching of electrolytes, soluble carbohydrates and soluble nitrogen, nucleic acid contents and dehydrogenase activity from sunflower and grass pea seeds, used as bioassay materials. Results showed that the plant extract of *Adhatoda* significantly inhibit both percentage and speed of germination, enhanced deleterious leaching of soluble carbohydrates, soluble nitrogen with concomitant enhancement of T_{50} value as well as electrical conductivity. Such changes were associated with the leaf extract- induced reduction of nucleic acid contents as well as total dehydrogenase activity.

A conclusion was made from this experiment that the plant extract potentially impaired anabolic activities in plants along with the visible seed germination parameters, and thus the plant seem to possess allelopathic property. From this study possible bio herbicide formulation using this plant species seems to be very promising.

Keywords: Allelopathy, bioassay, seed germination, solute leaching, nucleic acids, dehydrogenas

Introduction

The term allelopathy, derived from the Latin words allelon meaning 'of each other' and pathos meaning 'to suffer', refers to chemical inhibition of one species by another. Although the term allelopathy is most commonly used to describe the chemical interaction between two plants by releasing chemical substances into the environment, it has also been used to describe microbe-microbe, plant-microbe and plant-insect or plant-herbivore chemical interaction. The International Allelopathy Society(IAS) defined allelopathy as "any process involving secondary metabolites produces by plants, micro-organisms, viruses and fungi that influence the growth and development of agricultural and biological systems (excluding animals), including positive and negative effects" (Torres *et al*, 1996).

The excessive use of agrochemicals in recent time especially fungicides, which pose more carcinogenic risk than other pesticides (Anonyms, 1987), may give rise to undesirable biological effects on animals and human beings (Oueslati, 2003). Some other agrochemicals like herbicides, weedicides also showed harmful effects on our environment, if used in supraoptimal concentrations (Damjanoviae *et al*, 2008., Chon *et al*, 2006., Abd-Alla *et al*, 2001). Thus the development of biopesticides, bioherbicides and bioweedicides has been focused as viable strategy to overcome the hazardous effects of such agrochemicals. One of the best strategies is allelopathic interaction by using naturally occurring eco-friendly plant allelochemicals to control the growth and development of undesirable plants, weeds and pathogens in the agricultural field (Berthodsson, 2012., Alkhail, 2005., Callway and Aschehoug, 2000).

The profusely growing species like *Adhatoda vasica* shows their dominating growth behaviour by inhibiting the seed germination and growth of neighbour plant species by releasing some chemical compounds from their plant parts. The primary objective of the present investigation was to critically analyse the allelopathic potential of *Adhatoda vasica* on the basis of some physio-biochemical indices like seed germination behaviour, performance on viability and vigour of seeds and seedlings of two seed species (sunflower and grass pea) which are used as reliable bioassay material. To determine the efficacy of the putative allelochemicals of *Adhatoda*, the tested seeds were pre-treated with the *Adhatoda* leaf extract and measured the germinability, vigour and viability status, leaching of electrolytes, soluble carbohydrates and soluble nitrogen as well as macromolecular contents like DNA and RNA along with total dehydrogenase activity of the plant extract treated seeds in comparison to untreated and distilled water treated seed samples.

Materials and Methods

Certified seeds of sunflower (*Helianthus annuus* L.) and grass pea (*Lathyrus sativus* L.) were procured from authentic source. The percentage of germination at the time of purchase was 85.0% and 87.5%, respectively. The seeds were then stored separately in air tight containers for various experiments.

Preparation of plant extract: Leaf extracts of *Adhatoda vasica* Nees. Was prepared using 100 g fresh mature leaf sample and extracted with double distilled water. The volume was made up to 300 ml using double distilled water, filtered and finally the total volume was made exactly up to 300 ml.

Pretreatments: The experimental seeds (sunflower and grass pea) were separately immersed in the filtered extracts for 6 h,then washed thoroughly with distilled water and dried back to their original weight. Then the following tests were performed using the control and plant extract treated seed samples.

Germination and vigour test: Hundred (100) seeds of each sample were allowed to germinate in Petri dishes on filter paper at 26± 1^0 C in 12 h light and 12 h dark condition in temperature and moisture controlled seed germinator, and percentage of germination was recorded after every 24 h up to 10 days. In each case 3 replicates were taken. Dry weight of 10 days old uniformly growing seedlings, raised from the treated and untreated seeds was recorded in terms of mg/g fresh weight.

Test with leachates: Twenty (20) seeds of each sample in 3 replicates were steeped in 25 ml of double distilled water for 1, 4 and 24 h separately. The steeped water was then stirred well, decanted off and following tests were performed.

Conductivity test: Electrical conductivity of seed leachates was measured in a direct reading conductivity meter and recorded in terms of µMHO.

Soluble carbohydrate test: Soluble carbohydrate estimation of the leachate was done colorimetrically following the method of McCready *et al.* (1950) and the intensity of blue green colour was measured at 620 nm. Carbohydrate content was calculated in terms of µg/g/25 ml.

Soluble nitrogen test: Soluble nitrogen estimation was done following the method of Vogel (1961). The orange-yellow colour developed was measured using a colorimeter at 420 nm. The nitrogen content was calculated in terms of µg/g/25 ml.

Nucleic acid test: Extraction of DNA and RNA was done by employing the Cherry's (1962) method and estimation of the nucleic acids was done colorimetrically following the method of Markham (1955) with necessary modification made by Choudhury and Chatterjee (1970).

Dehydrogenase activity test: Seed samples after removing the seed coat were incubated in 0.1% TTC (2,3,5-triphenyl tetrazolium chloride) solution in dark for 24 h and subsequently 20 seeds of each sunflower and grass pea were separately immersed in 10 ml of 90% ethanol for 24 h to extract the red coloured formazan. Then O.D values of the coloured ethanol, extracted from seeds were measured at 470 nm. Intensity of colour indicates dehydrogenase activity which is directly correlated with the O.D values. This method for determination of total dehydrogenase activity was followed by Rudrapal and Basu (1979).

Results and Discussions

Table-1 shows that the plant extract of *Adhatoda vasica* significantly decreased the percentage of germination both in sunflower and grass pea with concomitant decrease of seedling dry weight along with the prolongation of the time period required for 50% germination (T_{50}). Such results indicated that the experimental plant extract can potentially decrease the vigour status of treated seed samples. Thus, allelopathic action of the plant extract is very significant from our results. Such allelopathic effect on seed germination behaviour treated with some other plant extracts was also reported by some other workers (Dogra and Sood, 2012., Salhi, *et al*, 2011., Zzet and Yusuf, 2004).

Inhibitory effect of putative allelochemicals of the experimental plant extract on treated seed samples was also judged by analysing the leaching of electrolytes, soluble carbohydrates and soluble nitrogen (Table -2). Increased amount of leaching of the soluble substances by the plant extracts irrespective of the seed samples clearly indicate that the allelochemicals possibly damaged the membrane which subsequently showed the deleterious effect of rapid leaching in comparison to control seed sample. This observation is also in conformity with previous observations (Ojha *et al*, 2013., Gupta and Narayan, 2010., Mitra and Prasad, 2010., Shah *et al*, 2006).

Allelopathic effect of the *Adhatoda* plant extract was further substantiated and proved from our results on the nucleic acid contents (Table- 3) and dehydrogenase activity (Table- 4) which was found to be much lower in plant extract treated seed samples. Dehydrogenase activity is generally used as very reliable index for the evaluation of seed vigour and seed viability. Low level of dehydrogenase activity indicates the lower viability and vigour status of the seeds. Such results, therefore, pointed out that in this experiment the treated seed samples both in sunflower and grass pea showed significant inhibitory effect as the allelochemicals of the plant extract prevented their germination and lowered vigour status by changing some biochemical activities of those treated seed samples (Hridya and Rajendra, 2014., Nayek and Bhattacherjee, 2012).

The experimental species *Adhatoda vasica* make a monospecific stand by displacement or by outcompeting the growth of other plant species in a particular growing area and it is clearly substantiated by negative modulation of germinability, metabolism and growth of the bioassay materials like sunflower and grass pea.

Literature Cited

Abd-Alla, M.S., Atalla, K.M and El-Swai, M.A.M. (2001). Effect of some plant waste extracts on growth and aflatoxin production by *Aspergillusflavus*. Annals Agric. Sci., Ain Shams Univ., Cario, 46:579-592.

Alkhail, AA. (2005). Antifungal activity of some extracts against some plant pathogenic fungi. Pak. J. Biol. Sci., 8(3):413-417.

Anonymous.(1987). Regulating pesticides in food. The Delancy Paradox. National Acadamy press, Washigton, DC.

Berthodsson, NO. (2012).Allelopathy-A Tool to Improve the Weed competitive ability of Wheat with Herbicide-Resistant Black-Grass (*Alopecurus-myosuroidesHuds.*) Agronomy, 2:284-294.

Callway, RM and Aschehoug, ET. (2000). Innvasive plants versus their new and old neighbors: a mechanism for exotic invasion. Science 290: 521-523. CrossRef, PubMed.

Table 1. Effect of seed pretreatment with leaf extract of *Adhatoda* on percentage germination and T_{50} values of sunflower and grass pea seeds and dry matter content of 10 days old seedlings, raised from untreated control, distilled water control and treated seeds

Seed sample as bioassay material	Treatments	Percent germination	T_{50} values of germination (Hours)	Seedling dry weight (mg/g fr wt.)
Sunflower	Untreated control	82.01	168.18	166.51
	Dist. water control	84.08	160.15	177.62
	Adhatodaextract	63.15	192.20	142.97
LSD (P = 0.05)		6.20	12.50	12.90
Grass pea	Untreated control	83.10	96.01	137.68
	Dist. water control	86.02	96.95	145.73
	Adhatoda extract	71.01	144.55	126.44
	LSD (P = 0.05)	8.01	10.98	9.02

Table 2. Effect of seed pretreatment with leaf extract of Adhatoda on leaching of electrolytes (LE); soluble carbohydrates (SC) and soluble nitrogen (SN) of untreated control, distilled water control and treated seeds

Seed sample as bioassay material	Treatments	Leaching of electrolytes (LE, µ MHO); soluble carbohydrates (SC, µg/g/25 ml) and soluble nitrogen (SN, µg/g/25 ml) after different intervals in hour.								
		1 Hour			4 Hours			24 Hours		
		LE	SC	SN	LE	SC	SN	LE	SC	SN
Sunflower	Untreated control	2.2	17.04	16.02	3.7	38.42	25.38	8.8	82.45	98.78
	Dist. water control	1.8	15.96	14.11	3.3	36.02	23.83	8.5	80.01	96.54
	Adhatoda extract	2.6	21.08	19.73	4.1	45.61	28.13	9.9	98.50	106.52
LSD (P = 0.05)		0.10	1.40	1.32	0.22	3.01	2.00	0.80	5.01	8.50
Grass pea	Untreated control	2.5	14.02	17.43	6.4	35.40	24.34	22.1	79.72	98.69
	Dist. water control	2.2	13.12	15.68	5.8	33.16	22.45	20.1	76.28	96.28
	Adhatoda extract	3.8	17.52	20.42	6.9	43.05	28.78	28.4	86.25	104.38
LSD (P = 0.05)		0.25	1.20	1.58	0.61	3.03	2.10	2.44	6.80	6.85

TABLE 3. Effect of seed pretreatment with leaf extract of*Adhatoda* on the changes of DNA and RNA contents of 10 days old seedlings, raised from untreated control, distilled water control and treated seeds

Seed sample as bioassay material	Treatments	Nucleic acid contents (µg/g fr. wt.)	
		DNA	RNA
Sunflower	Untreated control	392.70	795.98
	Dist. water control	408.20	801.73
	Adhatoda extract	363.28	767.23
LSD (P = 0.05)		22.50	25.80
Grass pea	Untreated control	367.62	766.29
	Dist. water control	382.50	778.73
	Adhatoda extract	323.60	742.69
LSD (P = 0.05)		25.15	27.05

TABLE 4. Effect of seed pretreatment with leaf extract of *Adhatoda* on the changes of dehydrogenase activity of untreated control, distilled water control and treated seeds

Seed sample as bioassay material	Treatments	Dehydrogenase activity (O.D)
Sunflower	Untreated control	1.12
	Dist. water control	1.20
	Adhatoda extract	0.98
LSD (P = 0.05)		0.09
Grass pea	Untreated control	1.21
	Dist. water control	1.25
	Adhatoda extract	1.08
LSD (P = 0.05)		0.10

Cherry, J.H. (1962).Nucleic acid determination in storage tissue of higher plants. Plant Physiol. 37: 667-678.

Chon, SU; Jennings, JA; Nelson, CJ.(2006). Alfalfa (*Medicagosativa* L.) autotoxicity: Current status. Allelopathy J., 18:57-80.

Choudhury, M.A., Chatterjee, S.K. (1970). Seasonal changes in levels of some cellular components in the abscission zone of Coleus leaves of different ages. Annals Bot. 34: 245-247.

Damjanoviae-vratnica, B; Dakov, T; Sukoviae, D; Damjnoaviae, J. (2008).Chemical composition and antimicrobial activity of essential oil of wild-growing *Salvia officinalis* L. from Montenegro. J. Essent. Oil Bear. Pl., 11:79-89.

Dogra, KS and Sood, SK. (2012).Phytotoxicity of Partheniumhysterophorus residues towards growth of three native plant species (*Acacia catechu* wild, *Achyranthesaspera* L. and *Cassia tora* L.) in Himachal Pradesh, India, Int. J. Plant Physiol. Biochem., 4(5):105-109. DOI:10.5897/ IJPPB11.009

Gupta, S and Narayan, R. (2010). Effect of applied leaf biomass of *Partheniumhysterophorus*, *Cassia obtusifolia* and *Achyranthusaspera* on seed germination and seedling growth of wheat and pea.Allelopathy Journal, 26:59-70.

Hridya, M and Rajendra, K. (2014). Allelopathic and mitodepressiveeffects of *Partheniumhystero-*

phorus L. leachates on ornamental sunflower. Global Journal of Bioscience and Biotechnology. 3(1) 1-5.

Markham, R. (1955). Nucleic acids, their components and related components. In: Modern methods of plant analysis Peach K, Tracy MV. (eds). Springer-Verlag. Berlin 4: 246-304.

McCready, R.N., Guggloz, J., Silviera, V., Owens, H.S. (1950). Determination of starch and amylase in Vegetables. Analytical chemistry. 22: 1156-1158.

Mitra, D. and Prasad, C. (2010).Allelopathic influence of Malabar nut (AdhatodavasicaNees.) on turnip (*Brassica rapa* L.): I. Seed and Seedling traits. Cruciferae Newsletter. 29:191-197.

Nayek, A. and Bhattcharjee, A. (2012).Investigation on allelopathic potential of *Eucalyptus globulus* Labill. And *Partheniumhysterophorus* L. Ph.D. Thesis.University of Burdwan., India.

Ojha, S., Pati, C.K. and Bhattacharjee, A. (2013). Evaluation of allelopahic potential of an aromatic exotic tree, *Melaleucaleucadendron* L. African Journal of Plant Science. 7(11): 558-560.

Oueslati, O. (2003). Allelopathy in two durum wheat (*Triticum durum* L.) varieties.AgricEcosys Env.96: 161-163.

Rudrapal, A.B., Basu, R.N. (1979). Physiology of hydration-dehydration treatments in maintenance of seed viability in wheat (*Triticumaestivum* L.) Ind J Experim Biol. 17:771-786.

Salhi, N., El-Darier, S and Halilat, MT. (2011). Allelopathic Effect of some Medicinal Plant on Germination of two Dominant Weeds in Algeria. Advances in Environmental Biology. 5(2): 443-446.

Shah, S.R.U., Qasim, M., Khan, I.A and Shah, S.A.U. (2006). Study of medicinal plants among weeds of wheat and maize in Peshawar region.Pakistan Journal of Weed Science Research. 12:191-197

Torres, A., Oliva, R.M., Castellano, D., Cross, P. (1996). First World Congress on Allelopathy. A science of the Future, SAI (University of Cadiaz), Spain, Cadiaz, p.278.

Vogel, A.I. (1961). A text book of quantitative inorganic analysis.pp, 783-784. The English Language Book Society. Longmans Green & Co, Ltd. London.

Zzet, K.L., Yusuf, Y. (2004). Allelopathic Effects of Plant Extracts Against Seed Germination of some Weeds. Asian Journal of Plant Sciences. 3(4):472-475.

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Heterosis Studies for Grain Yield, its Component Traits and Quality of QPM Maize (*Zea Mays* L.)

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Abstract

A field experiment was undertaken to estimate the heterotic, heterobeltiotic and standard heterotic effects of 13 characters of 50 maize hybrids developed by ten parents in maize during Kharif seasons of 2006 to 2007 on Research Farm C.C.R. (P.G.) College Muzaffarnagar, U.P. In this study ten lines as female parents and five testers as male parents were crossed in line x tester matting design. The Inbred lines viz. DMRQPM-60, DMRQPM-28-3, DMRQPM-58, DMRQPM-75, DMRQPM-18, DMRQPM-28-5, DMRQPM-03-101, DMRQPM-03-102, DMRQPM-03-117, DMRQPM-03-118 were selected as lines and five inbred lines viz., DMRQPM-03-104, DMRQPM-03-105, DMRQPM-28-5, DMRQPM-03-107 and DMRQPM-03-121 were selected as testers for line x tester cross. Out of 50 crosses, heterosis for grain yield per plant was significant and positive in 45 crosses over better parent and 46 crosses over standard check (HIM-129) respectively. Among them crosses DMRQPM-03-102xDMRQPM-03-121,DMRQPM-03-117xDMRQPM-28-5, DMRQPM-03-117 x DMRQPM-03-104 and DMRQPM-28-5xDMRQPM-03-105 had high mean performance and standard heterosis over check HIM 129 and other yield contributing characters like number of kernels per row, 100-kernel weight, number of kernel rows per ear, ear diameter and ear length. For early tasseling and early silking crosses DMRQPM-03-102 x DMRQPM-03-105 and DMRQPM-75 x DMRQPM-28-5 and for higher protein content crosses DMRQPM-60 x DMRQPM-28-5 and DMRQPM-03-102 x DMRQPM-03-107 were identified for qualitative hybrids. Testing of these hybrids in all India coordinated trials across the different states of the country may result in identification of better hybrids in the near future.

Keywords: Heterosis, Yield, Quality Protein Maize (QPM), CIMMYT, Maize, Protein content

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops and occupies a prominent position in global agriculture after wheat and rice. In India, maize ranks third next to rice and wheat (Centre for Monitoring Indian Economy 2014). It is regarded as most important cereal crop in the world agriculture economy both as food for human beings and a feed for animals and industrial uses. Maize crop grown over an area of 67.77 million hectare produces 15.09 million tonnes of grain with an average productivity 1953 kg/ ha. (Asif *et.al.* 2014). Quality Protein Maize (QPM) breeding program in 1970s developed a number of nutritionally superior opaque-2 composite varieties. Three promising varieties were released for commercial cultivation. Chemical analyses of these composites showed superior amino acid balance than normal maize varieties. Dr. Hugo Cordova had led the CIMMYT effort to develop and spread high yielding QPM hybrids

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and germplasm. These QPM hybrids having high yield potential comparable to normal maize hybrids with better protein quality are found suitable for commercial cultivation. Normal maize hybrids replaced with QPM hybrids will ensure better income to the farmers and higher nutrition to the consumers. This will contribute to food and nutritional security to the country especially to the poor and tribal farmers, where maize is consumed as staple food. QPM will also provide better quality feed and fodder to poultry, cattle, swine, fish meal industries etc.

Presence of high amount of lysine and tryptophan and low amount of leucine has given QPM a special and distinctive status among cereals. Hence, replacement of common maize by QPM is the most effective and attractive measure to meet quality protein needs and raise the human nutritional status. Thus there is an urgent need to popularize QPM among our population especially the malnourished segments of the society. If QPM is utilized in diversified ways by converting them into a variety of products for use, as infant food, health food/mixes, convenience foods, specialty foods and emergency ration, it is possible to make a significant impact on health status of the malnutrition problem. These can also be prepared in villages and thus could be a great source of rural entrepreneurship.

The major bottleneck encountered in commercial release of single cross hybrid has lack of good, vigorous, high yielding inbred lines as seed parent and other problem is that of poor pollen parents. Maize is a highly cross pollinated crop and the scope for the exploitation of hybrid vigour will depend on the direction and magnitude of heterosis and also the type of gene action involved (Ruswandi et.al 2015). The magnitude of heterosis provides information on extent of genetic diversity of parents in eveloping superior F1s so as to exploit hybrid vigour and has direct bearing on the breeding methodology to be adapted for varietal improvement. Hence, the present investigation was carried out to know the direction and magnitude of heterosis in maize.

Materials and Methods

The experiment with 10 lines, 5 testers and 50 crosses along with suitable check (HIM-129) was laid out in randomized block design (RBD) with three replications at the Research Farm C.C.R. (P.G.) College Muzaffarnagar, U.P. during *kharif* 2006-07. It was conducted during Kharif season of 2006 to 2007 at Research Farm C.C.R. (P.G.) College Muzaffarnagar, U.P. The soil of the experimental was Gangetic alluvium with clay loam in texture (38% clay) having 1.46 Mg/m3 bulk density. The surface soil had 6.4 pH (1:2.5), 0.42 dS/m electrical conductivity, 3.8 g/kg soil organic carbon and 15.3 cmol(p^+)/kg) cation exchange capacity. The soil was low in available N (141 mg/kg), medium in available P (21.1 mg/kg) and available K (161 mg/kg). The area represents sub-tropical humid climate. The experiment comprises of ten lines as female parents and five testers as male parents were crossed in line x tester matting design. Inbred lines viz. DMRQPM-60, DMRQPM-28-3, DMRQPM-58, DMRQPM-75, DMRQPM-18, DMRQPM-28-5, DMRQPM-03-101, DMRQPM-03-102, DMRQPM-03-117, DMRQPM-03-118 were selected as lines and five inbred lines *viz.*, DMRQPM-03-104, DMRQPM-03-105, DMRQPM-28-5, DMRQPM-03-107 and DMRQPM-03-121 were selected as testers for line x tester cross. All the parents along with their 50 F1s were grown in randomized block design with three replications. Each genotype consisted of three rows of 3.00 m long and 11 plants in each row. The spacing given was 45 cm between rows and 30 cm within a row. Observations were recorded on fifteen randomly tagged competitive plants from each genotype and data were subjected to Computation of heterosis for all characters were carried out as per procedure suggested by Fonesca and Patterson (1968). SPSS ver- (7.5) along with MS-Excel software was used to do all statistical analysis.

Results and Discussions

Analysis of variance revealed significant differences for all the 13 quantitative traits studied which was presented in Table 1. This indicates considerable variability existed among genotypes for

TABLE 1. ANOVA for parents and hybrids of maize

Source of variance	d.f.	Plant height (cm)	Days to 50% tasseling	Days to 50% silking	Tassel length	Ear length	No. of kernels/row	Ear diameter	No. of kernel rows/ear	100-kernel wt. (g)	Ear weight	Grain yield/plant	Protein content	Sugar content
Replication	2	6.37	2.21	5.45	4.03	1.16	3.92	0.055	0.102	3.21	10.79	5.76	0.73	0.020
Parents (P)	14	22.76**	5.95	5.71	32.13**	3.07**	0.95	0.073	0.808	4.53	109.96**	186.30**	0.48	0.062*
Females (F)	9	16.49**	5.34	5.39	37.20**	3.51**	1.07	0.097	0.589	4.26	115.80**	221.76**	0.67	0.073*
Male (M)	4	37.92**	8.13*	7.78	2.20	0.65	0.48	0.034	1.496**	6.06	110.66**	122.45**	0.12	0.044
F x M	1	18.48**	2.68	0.29	106.21**	8.76**	1.78	0.010	0.025	0.77	54.62**	122.57**	0.28	0.034
Hybrids (H)	49	70.49**	6.28	4.74	9.20*	1.72	11.66**	0.034	0.521	4.71	111.43**	470.21**	0.98	0.017
P x H	1	2943.03**	4.58	0.94	1682.1**3	103.49**	25.39**	0.346**	80.959**	111.10**	4065.34**	4738.19**	80.60**	2.584**
Error	128	4.53	3.91	3.73	5.28	1.49	2.51	0.077	0.538	3.30	8.73	6.26	0.54	0.029

* Significant at 5% level; ** Significant at 1% level.

all the characters studied. The mean squares due to parents and crosses were highly significant for plant height, tassel length, ear length, ear weight and grain yield per plant which indicated that the parents chosen were diverse and with a different genetic background. Similarly, significant mean squares due to parents vs. crosses indicated presence of average heterosis for all the characters. Considerable amount of heterosis was observed for all the thirteen characters under study; however the magnitude varied with characters presented in Table 2.

In maize breeding programme aimed at developing early maturing inbreds/hybrids, days to 50% tasselling and days to 50% silking are two vital attributes for maturity. Heterosis in negative direction is desirable for days to 50% tasseling, days to 50% silking and days to maturity. For Days to 50% tasseling, 17 crosses over better parent and 13 crosses over standard check exhibited significant negative heterosis. The range varied from -13.98 (DMRQPM-03-102 x DMRQPM-03-105) to 3.87 % (DMRQPM-28-5 x DMRQPM-03-121) over better parent and from -12.08 (DMRQPM-03-102 x DMRQPM-03-105) to 2.71 % (DMRQPM-03-101 x DMRQPM-03-107) over standard check. The range of heterosis for days to 50% silking varied from -10.00 (DMRQPM-03-102 x DMRQPM-03-105) to 3.55 % (DMRQPM-03-101 x DMRQPM-03-107) and from 7.06 (DMRQPM-03-102 x DMRQPM-03-105) to 2.88 % (DMRQPM-03-101 x DMRQPM-03-107) over standard check, respectively. Negative heterosis for these three characters indicates the possibilities for breeding of maize for earliness and results were in conformity with earlier reports of, Sudhir et al. (2004), Mohanraj et al. (2005), Chattopadhayay and Dhiman (2006) and Dar et al. (2007).

The range of heterosis for plant height varied from -2.06 (DMRQPM-28-3 x DMRQPM-03-121) to 19.67% (DMRQPM-60 x DMRQPM-03-104) and -7.80 (DMRQPM-03-118 x DMRQPM-28-5) to 25.91 % (C DMRQPM-60 x DMRQPM-03-104) over better parent and standard check (HIM 129), respectively. The range of heterosis for tassel length and ear length varied -2.80 (DMRQPM-03-118 x DMRQPM-28-5)

Table 2. The range of heterobeltiosis, standard heterosis and number of crosses showing significant heterobeltiosis and standard heterosis for 13 characters in single cross hybrids of maize

Sl.No.	Traits	Range heterobeltiosis (%)	Range of standard checks (%)	Number of crosses showing significant	
				Better parent	Standard checks
1.	Plant height (cm)	-2.06-19.67	7.8-25.91	35	50
2.	Days to 50% tasseling	-13.98-3.87	-12.08-2.71	17	13
3.	Days to 50% silking	-10.00-3.55	-7.06-2.88	12	10
4.	Tassel length	-2.8-28.52	15.76-30.45	40	50
5.	Ear length	-9.28-36.53	13.16-43.97	40	50
6.	No. of kernels/row	-11.26-18.59	19.39-59.54	34	50
7.	Ear diameter	-6.16-10.46	-4.59-9.73	36	50
8.	No. of kernel rows/ear	-5.26-23.19	7.14-25.00	46	50
9.	100-kernel wt. (g)	-8.24-33.59	4.47-36.22	41	50
10.	Ear weight	-17.68-45.41	8.23-61.89	42	50
11.	Grain yield/plant	-23.89-58.9	-6.43-85.10	45	46
12.	Protein content	1.09-33.13	5.81-32.40	45	50
13.	Sugar content	-6.37-20.64	6.75-19.44	47	50

to 28.52 % (DMRQPM-03-117 x DMRQPM-03-121) and -9.28 (DMRQPM-75 x DMRQPM-28-5) to 36.53 % (DMRQPM-28-5 x DMRQPM-03-104) over better parent. These results were comparable with findings of Mohanraj *et al.* (2005), Melkamu *et.al* 2013.

For ear weight, majority of the crosses recorded high heterobeltiosis in the present study. Heterosis over standard check HIM 129, all the crosses had positive and significant heterosis. The range of heterobeltiosis and standard heterosis varied from -17.68 (DMRQPM-28-3 x DMRQPM-03-121) to 45.41 % (DMRQPM-18 x DMRQPM-03-104) and 8.23 (DMRQPM-28-3 x DMRQPM-03-121) to 61.89 % (DMRQPM-28-3 x DMRQPM-03-104) respectively. These results are in comparable with findings of Mohanraj *et al.* (2005) Singh *et al.* (2010), Ram Raddy 2011 and Abdel et.al 2014.

Grain yield per plant is the important yield characters. Grain yield is a complex quantitative character which is influenced by other ancillary and component characters. Hence all changes in the components would not be expressed as changes in yield but all changes in yield would be accompanied by changes in one or more components. Reddy *et al.* 2015 suggested that there could be no gene system for yield per se since yield is an end product of the multiplicative interaction between its various components. Rajesh *et al.* 2014 however, has shown that heterosis will be expressed when we have two conditions (a) Presence of some level of dominance and (b) relative difference in gene frequency of the two parents to determine the magnitude of heterosis expressed in crosses. Grain yield per plant is a multiplicative product of several basic components of yield. The increased grain yield is definitely because of increase in one or more than one yield components. The major reason of high degree of heterosis was due to genetic divergence in the parents, though the predominance of dominant gene action was operating in the inheritance of traits.

In the present study, out of 50 crosses, heterosis for grain yield per plant was significant and positive in 45 crosses over better parent and 46 crosses over standard check (HIM-129) respectively. Among these, five crosses DMRQPM-03-118 x DMRQPM-28-5 (49.78%), DMRQPM-03-118 x DMRQPM-03-121 (42.62%), DMRQPM-28-5 x DMRQPM-03-105 (50.56), DMRQPM-03-102 x DMRQPM-03-121 (50.96%), DMRQPM-03-117 x DMRQPM-28-5 (58.90%) recorded highest positive significant heterosis over better parent and positive significant standard heterosis over HIM 129 were DMRQPM-03-117 x DMRQPM-28-5 (85.10%), DMRQPM-28-5 x DMRQPM-03-105 (78.61%), DMRQPM-03-117 x DMRQPM-03-104 (49.39%), DMRQPM-03-117 x DMRQPM-03-107 (48.84%), DMRQPM-75 x DMRQPM-03-104 (48.22). Several workers reported positive significant heterosis for exploiting hybrids vigour Kaushik *et al.* (2004), Mohanraj *et al.* (2005), Ram Raddy 2011, Asif *et.al.* 2014 and Abdel *et.al.* 2014.

The variation in magnitude of heterosis reported by several workers may be due to differences in genotypes included in the study and different environments in which the studies were conducted. The above review indicates high heterosis for various characters can be obtained by crossing widely differencing parents. Reddy *et al.* (2004), Reddy and Ahuja (2004) studied that crosses were superior, with high mean per se values coupled with high heterosis for grain yield per plant.

The range of heterosis for 100- kernel weight varied from -8.24 (DMRQPM-75 x DMRQPM-03-107) to 33.59 % (DMRQPM-03-117 x DMRQPM-03-107) over better parent and from -4.47 (DMRQPM-03-118 x DMRQPM-03-121) to 36.22 % (DMRQPM-28-5 x DMRQPM-28-5) over standard check. For number of kernels per row, the range of heterobeltiosis and standard heterosis varied from -11.26 (DMRQPM-03-117 x DMRQPM-03-104) to 18.59 % (DMRQPM-28-3 x DMRQPM-03-104) and 19.39% (DMRQPM-03-117 x DMRQPM-03-104) to 59.54 % (DMRQPM-28-3 x DMRQPM-03-104) respectively. Similarly, for number of kernel rows per ear, heterosis ranged from -5.26 (DMRQPM-75 x DMRQPM-03-107) to 23.19 % (DMRQPM-03-118 x DMRQPM-03-105) over better parent and from 7.14 (DMRQPM-75 x DMRQPM-03-107) to 25.00 % (DMRQPM-03-101 x DMRQPM-

03-107) over standard check. The range of heterosis for ear diameter varied from – 6.16 (DMRQPM-03-118 x DMRQPM-03-105) to 10.46 % (DMRQPM-03-101 x DMRQPM-28-5) over better parent and -4.59 (DMRQPM-28-5 x DMRQPM-03-121) to 10.46 % (DMRQPM-03-101 x DMRQPM-28-5) over standar check.

The majority of the crosses exhibited high heterobeltiosis and in addition to high per se performance for protein content and sugar content. Standard heterosis for protein content and sugar content was recorded in all the crosses. Crosses DMRQPM-60 x DMRQPM-28-5, DMRQPM-60 x DMRQPM-03-107, DMRQPM-75 x DMRQPM-03-105, DMRQPM-03-102 x DMRQPM-03-107 were recorded highest heterosis over better parent and standard checks (HIM 129) for protein content. These conformed to the findings of Srivastava *et al.* (2003), Melkamu *et al.* (2013).

Conclusion

The entire results of heterosis, heterobeltiosis and standard heterosis indicated that the parents involved in the crossing should have one high *per se* performing parent and over dominance may be the cause of heterosis. The main reason in the cross combinations or uncommon genes for a trait is the cause to exploit the maximum exploitable level of heterosis in maize. The crosses for grain yield/plant DMRQPM-03-102xDMRQPM-03-121, DMRQPM-03-117xDMRQPM-28-5, DMRQPM-03-117 x DMRQPM-03-104 and DMRQPM-28-5xDMRQPM-03-105 had high mean performance and standard heterosis over check HIM 129 and other yield contributing characters like number of kernels per row, 100-kernel weight, number of kernel rows per ear, ear diameter and ear length. For early tasseling and early silking crosses DMRQPM-03-102 x DMRQPM-03-105 and DMRQPM-75 x DMRQPM-28-5 and for higher protein content crosses DMRQPM-60 x DMRQPM-28-5 and DMRQPM-03-102 x DMRQPM-03-107 were identified for qualitative hybrids.

Literature Cited

Abdel, M.M.A., Sultan, M.S., Sadek, S. E. and Shalof, M.S. (2014). Estimation of heterosis and genetic parameters for yield and yield components in maize using the diallel cross method. *Asian Journal of Crop Science* **6**: 101-111.

Asif, A., Hidayat, ur., Rahman, Liaqat S, Kashif, A.S. and Shamsur, R. (2014). Heterosis for grain yield and its attributing components in maize variety Azam using Line × Tester analysis method. *Academia Journal of Agricultural Research* **2:** 225-230.

Centre for Monitoring Indian Economy (2014). Annual Reports, Centre for Monitoring Indian Economy Private Limited. Apple Heritage, Mumbai.

Chattopadhyay, K. and Dhiman, K.R. (2006). Heterosis for ear parameters, crop duration and prolificacy in varietal crosses of maize (*Zea mays* L.). *Indian Journal. Genetics and Plant Breeding*, **66**(1): 45-46.

Dar, S.A., Ali, G., Rather, A.G. and Khan, M.N. (2007). Combining ability for yield and maturity traits in elite inbred lines of maize (*Zea mays* L.). *International Journal. Agricultural Science* **3**(2): 290-293.

Fonesca, S. and Patterson, F. L. (1968). Hybrid vigour in a seven parent diallel cross in common wheat (*Triticum aestivum* L.). *Crop Science*. 8: 85-88.

Kaushik, S.K., Tripathi, R.S., Rama Krishna, K., Singhania, D.L. and Rokadia, P. (2004). An assessment of protein and oil concentration in heterotic crosses of maize (*Zea mays* L.). *SABRAO Journal Breeding and Genetics* **36**(1): 35-38.

Melkamu, E., Tadsse, D. and Yigzaw, D. (2013). Combing ability, gene action and heterosis estimation in quality protein maize. *International Journal of Scientific and Research Publications* **3**:1-17.

Mohanraj, K. and Gopalan, A. (2005). Heterosis a cross reveral characters in maize (*Zea mays* L.). *Plant Archives.*, **5**(1): 311-312.

Rajesh, V. Sudheer, Kumar S., Narsimha, Reddy V. and Siva, Sankar A. (2014). Heterosis studies for grain yield and its component traits in single cross hybrids of maize (*Zea mays* L.). *International*

Journal of Plant, Animal and Environmental Sciences **4:** 304-306.

Ram, Reddy V, Seshagiri, Rao A. and Sudarshan, M.R. (2011). Heterosis and combining ability for grain yield and its components in maize (*Zea mays* L.). *Journal of Research ANGRAU* **39**: 6-15.

Reddy, D.M. and Ahuja, V.P. (2004). Heterosis studies over environments for grain yield and its components in maize (*Zea mays* L.). *National Journal Plant Improvement* **6**(1): 26-28.

Reddy, R.V., Jabeen, F. and Sudarshan R.M. (2015). Heterosis studies in diallel crosses of maize for yield and yield attributing traits in maize (*Zea mays* L.) over locations. *International Journal of Agriculture, Environment and Biotechnology* **8**(2): 271-283.

Ruswandi, D., Supriatna, J., Makkulawu, A.T., Waluyo, B., Marta, H., Suryadi, E. and Ruswandi, S. (2015). Determination of combining ability and heterosis of grain yield components for maize mutants based on Line×Tester analysis. *Asian Journal of Crop Science* **7**: 19-33.

Singh, S.B., Gupta, B.B. and Anjani, K.S. (2010). Heterotic expression and combining abilty for yield and its components in maize (*Zea mays* L.). *Progressive Agriculture* **10**: 275-281.

Srivastava, A. and Singh, I.S. (2003). Heterosis and combining ability for yield and maturity involving exotic and indigenous inbred lines of maize (*Zea mays* L.). *Indian Journal Genetics and Plant Breeding* **63**(4): 345-346.

Sudhir, Sharma, Sain Dass and Rakesh Kumar, (2004). Heterosis for maturity traits in maize (*Zea mays* L.). *Annals of Agric. Bio. Research* **9**(1): 19-20.

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Sustainability of Farm and Farmers through Eco-Friendly IFS Approach

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Abstract

The income of the small farmers that comprises over ¾ of the farmers is too meagre to support the families. The problem cannot be more excruciating in arid and semi arid area under the jurisdiction of SDAU where harsh climatic conditions peppered with wreaking problems of agriculture like fragmentation of holdings, dissipating natural resources base, back breaking cost of inputs etc are the rules rather than aberrations. The agriculture in North Gujarat is largely animal husbandry based. SDAU developed a model of integrated different agriculture activities entailing soil, plant, animal and farmers family as a functional unit to harness more regular income per unit of area with sustainability of health of each component including natural resources base and farmer. The system is based on in vogue cropping system on 0.70 ha of 1.00 ha farm viz; (i) green gram –mustard- summer pearl millet (0.24 ha), (ii) groundnut-wheat-fodder pearl millet (0.08 ha), (iii) green gram- castor relay (0.32 ha) and (iv) fodder cowpea - lucerne + chicory (0.06 ha) to ensure annual calorie and nutritional requirement of the family. Both income and health were made more sustainable by growing fruits and vegetable in two tiers on 0.25 ha. The soil health was taken care of by including pulses in cropping system, making microbes enriched vermin-compost from the waste and dung of the two buffaloes reared on 0.04 ha. Farm wastes were recycled within the system which obliterated the need to purchase off-farm inputs. The internal bunds were used for growing fodder while on boundaries quick growing timber tree like *Alianthus* were planted to brace up income. The model had a provision of farm pond (0.01 ha) for water harvesting and well recharging on low lying depression of the farm. The model also entailed trees like *glaceredia* at regular interval whose nutritious leaves were lopped and added to soil to enhance soil fertility. The system has been functional for the last five years and the cursory analysis of the investment indicated that system is good enough to provide daily income of . 990/day with engagement of 0.84 unit of labour/day. The income can be further ramped up by growing medicinal annuals and herbs on bunds and including other components of farming like poultry, goatary, piggery etc. The continuous sustainable income and livelihood security throughout the year can be fruitful to check urban migration.

Introduction

Indian economy is predominantly rural and agriculture oriented where the declining trend in the average size of the farm holding poses a serious problem. In agriculture 84.00 per cent of the holding is less than 2 acres. Majority of them are dry lands and even irrigated areas depend on the vagaries of monsoon. In this context, if farmers concentrated on crop production they will be subjected to a high degree of uncertainty in income and employment. Hence, it is imperative to evolve suitable strategy for augmenting the income of the small and marginal farmers by combining to increase the productivity and supplement the income. In an agricultural country like India, the average land holding is very small. The population is steadily increasing without any possibility of increase in land area. The income from cropping for an average farmer is hardly sufficient to sustain his family. The farmer has to be assured of a regular income for a reasonable standard of living by including other enterprises. In view of the above facts there is strong need to commercialize agriculture and in order to ensure an all round development of farming families farming should be considered as a system in which crop and other enterprises that are compatible and complimentary are combined together. The study of farming systems and application of farming systems approaches can bring a ray of hope for the betterment of farmers. Keeping all these factors in mind the present study was conducted to suggest which particular mixture of crop, dairy and other farming systems can provide maximum benefit.

Materials and Methods

The present study was carried out Centre for Research on Integrated farming Systems, SDAU, Sardarkrushinagar of Gujarat State. Farming system which integrates natural resources and regulation into farming activities to achieve maximum replacement of off-farm inputs, secures sustainable production of high quality food and other products through

Table 1. 1.0 Hectare IFS Model

Enterprises identified	Area (ha)	Treatment / Remarks
I. Crops	0.70	Cropping Systems: C_1:Castor + Greengram (0.32) C_2: G'nut - Wheat – Multicut Fodder Rajka Bajra (0.08) C_3: Greengram – Mustard - Pearlmillet (0.24) C_4:.Hy. Napier + Cowpea(F) – Lucerne + Fodder Chicory (0.06)
II. Multistoried Horticulture Fruits and Vegetables	0.25	Fruit trees 1. Mango : 8m x 8m (40 plants) 2.Lemon: In between two rows at 4 m distance (80 plants) 3.Custard apple: In between 2 plants of mango (36 plants) 4.Seasonal Vegetables in between fruit trees
III.Boundary plantation		Boundary plantation I. Timber wood/Fruit/ Vegetable / Medicinal plants 1. Ardusa : 10 6. Mulberry : 03 2. Eucalyptus : 10 7. Drum stick : 15 3. Subabool : 10 8. Aonla : 03 4. Custard apple : 10 9. Bamboo : 01 5. Jambun : 04 10. Teak : 35 II. Fodder crops: Dhaman and Hybrid Napier on bunds
IV. Livestock	0.025	Mehsani breed Buffaloes (Two)
V. Vermicompost, compost and nursery unit	0.010	To be filled by FYM, Farm wastes and cattle feed wastage. Raising nursery for fennel, brinjal, tomato, onion etc.
VI. Water harvesting for recharging	0.015	IR is 15cm/hr. Source of irrigation is tube well. GWT is depleting 2 to 3 m every year. Electricity consumption is too high. Runoff water harvesting is needed.
TOTAL	1.000	

ecologically preferred technologies, sustained farm income, reduction of sources of present environment pollution generated by agriculture and sustains the multiple function of agriculture. When different enterprises are dependent, complementary and supplementary to each other, they interact among themselves and affect the others. Such a mixed farming system is termed an “integrated farming system”. IFS experiment is going on with different components viz., 1. Crops (0.70 ha), 2. Multistoried horticultural crops (0.25 ha), 3. Boundary plantation, 4. Dairy unit with two Mahesani breed buffaloes (0.025 ha), 5. Vermicompost and Nursery unit (0.01 ha) and 6. Water recharging unit (0.015 ha). The different component mention in Table. 1 with allotted area as per different component

Results and Discussion

Integrated farming systems of crops with allied enterprises, implemented in on-station situations. Research studies have demonstrated the technical feasibility and economic viability of integrated farming systems. Besides facilitating cash income, integrated farming system generates additional employment for family labour and minimizes the risk associated with conventional cropping system. It also sustains soil productivity through the recycling of organic nutrient sources from the enterprises involved. The advantage of using low-cost or no-cost material at farm level for recycling is reduced production costs, with improved farm income.

There are different four type of cropping systems (Table.2). Among four type of cropping systems, C_1: castor + Greengram cropping system indicated maximum net return . 36,703/ 0.32 ha area. C_2: Groundnut - Wheat -Multicut fodder pearlmillet cropping system received . 19,855/0.08 hectare area. C_3: GG-Mustard-Pearlmillet cropping system indicated . 33,500/0.24 hectare area and fourth cropping system for fodder purpose due to animal unit in IFS model received . 25,894/0.06 hectare area. Total net return from all cropping systems . 1,15,952 /0.70 hectare area.

In Horticulture unit, growing different type of *kharif*, rabi and summer season vegetables and end of year getting . 43250 /0.25 hectare horticulture unit area. Among horticulture plants Income from fruits is to be expected from fourth year and onwards and the production of vegetables decreases as age of fruit tree increase.

As per the boundary plantation unit, growing grasses and hybrid napier, ardusa, drumstick and subabul on bund. As per Table.3 boundary plantation total net return received . 1,93,086 in 2014-15.

As per the IFS model, dairy unit and

TABLE 2. Yield from cropping systems component

SN	Cropping Systems	Area	Production (kg)			Returns (.)	
		(ha)	K	R	S	Gross return	Net profit
1.	C_1: Castor + Greengram	0.32	65	1410	-	55,536	36,703
2.	C_2: G’nut - Wheat -Multicut Fodder pearlmillet	0.08	155	410	6200	33,920	19,855
3.	C_3: Green gram-Mustard - Pearlmillet	0.24	201	468	1110	57,111	33,500
4.	C_4: Hy. Napier + Cowpea (F) - Lucerne + Fodder Chicory	0.06	4510 + 1220	5700	-	33,680	25,894
	Total	0.70				1,80,247	1,15,952

Table 3. Yield from Horticulture component

S N	Horticultural and Vegetables components	Area (ha)	Gross return (.)	Cost of cultivation (.)	Net profit (.)
1.	Mango	0.25	-	-	-
2.	Lemon	-	1800	-	-
3.	Custard apple	-	-	-	-
4.	Seasonal vegetables	-	55,763	21,830	33,933
	Total from all the fruits and vegetables	0.25	57,563	21,830	35,733

Table 4. Yields from Boundary plantation

Production from Boundary plantation (kg)	Gross return (.)	Cost of cultivation (.)	Net profit (.)
➩ Grasses and Hy. Napier:7600 kg ➩ Ardusa leaves:2020 kg ➩ Ardusa twings: 1515 kg ➩ Drumstrick : 500 kg ➩ Subabool lopping : 130 kg ➩ Increase in timber wood : 1576 cu.ft.	1,97,286	4,200	1,93,086

Table 5. Economics of dairy and vermicompost unit

Dairy product	Quantity (Lit or kg)	Rate /kg (.)	Gross return (.)	Net return (.)
Milk	1362	36.6	49860	
Vermicompost	6500	4	26000	
Shed waste	2355	0.35	824	
Urine	7600	0.2	1520	
Sold animal			72100	
	Total		150304	16,645

vermicompost which having two Mehsani breed buffaloes which indicated that gross return of . 1,50,304 and total cost . 1,33,659. Total net profit from dairy and vermicompost unit was obtained . 16,645/0.035 hectare area.

IFS experiment is going on with different components viz., 1. Crops (0.70 ha), 2. Multistoried horticultural crops (0.25 ha), 3. Boundary plantation, 4. Dairy unit with two Mahesani breed buffaloes (0.025 ha), 5. Vermicompost and Nursery unit (0.01 ha) and 6. Water recharging unit (0.015 ha).

Total net profit . 1, 15, 952 was received by crop component from 0.70 ha area. From multistoried horticultural and intercrops with seasonal vegetables (0.25 ha) recorded . 35,733 and boundary plantation recorded . 1,93,086. Dairy and Vermicompost unit recorded net profit of . 16,645. Total net profit from all the component of IFS Model was . 3, 61,416. Integration of different farming systems were also found beneficial by Ramrao *et al.* (2005), Sharma *et al.* (2008) and Channabasavanna *et al.* (2009) in their research of different States.

TABLE 6. Economics of different IFS components (2014-15)

S.N	Name of IFS components	Area (ha)	Gross return (.)	Total cost (.)	Net return (.)
1	Cropping systems	0.70	1,80,247	64,295	1,15,952
2	Horticultural and Vegetables crops	0.25	57,563	21,830	35,733
3	Boundary plantation	—	1,97,286	4,200	1,93,086
4	Livestock +Vermicompost	0.035	1,50,304	1,33,659	16,645
Total		1.00	5,85,400	2,23,984	3,61,416
	Man days		0.84/day		
	Per day income		. 990 /day		

Literature Cited

Ramrao, W. Y., Tiwari, S. P. & Singh, P. (2005). Crop-livestock integrated farming system for augmenting socio-economic status of smallholder tribal of Chhattisgarh in central India. *Livestock Research for Rural development,* Volume **17**, Article 90.

Sharma, Y. K., Bangarva, G.S. & Sharma, S.K. (2008). Farming System Based Constraints Faced by Farmers. *Indian Research Journal of Extension Education*, **8** (1), pp. 57-59.

Channabasavanna, A. S., Biradar, D. P., Prabhudev, K. N. & Mahabhaleswar Hegde. (2009). Development of profitable integrated farming system model for small and medium farmers of Tungabhadra project area of Karnataka. *Karnataka Journal of Agric. Sci.*, **22**(1), pp. 25-27.

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Effect of Different Irrigation Levels on Growth, Yield and Water Productivity of Tuberose in the Indo-Gangetic Plain

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Abstract

A field investigation was conducted during 2012 and 2013 in the Indo-Gangetic plain of West Bengal to find out the effect of three irrigation levels (I_1: IW/CPE 0.4, I_2 = IW/CPE 0.8, I_3 = IW/CPE 1.0) on growth, yield and water productivity of three cultivars (V_1: Prajwal, V_2: Calcutta Single, V_3:Calcutta Double) of tuberose plant (*Polianthes tuberose* L.). The experiment was laid out in a factorial randomized block design with three replications. The results showed that irrigation schedule at IW/CPE 1.0 significantly increased the growth characters, yield attributes and flower yields of plant, which were competitive with IW/CPE 0.8. Calcutta double cultivar performed better than Calcutta single and Prajwal in promoting growth, yield characteristics and yields at all irrigation levels, the more so in higher irrigation level than in lower irrigation level. However, in consideration of relatively higher flower and bulb yields and higher water productivity from tuberose, irrigation schedule at IW/CPE 0.8 with Calcutta double is advocated in the Indo-Gangetic plain of West Bengal.

Key words: *Polianthes tuberose*, growth character, flower and bulb yield, irrigation schedule

Introduction

Tuberose (*Polianthes tuberose* L.) is one of the most popular bulbous ornamental plants in India from the aesthetic and commercial point of view. It belongs to the family Amarylidaceae, produces attractive, elegant and delightful fragrant white flowers (De Hertogh and Le Nard, 1993) having excellent keeping quality and stand long distance transportation (Patel *et al.,*2006). It is a multipurpose flower, which has great economic value as a cut flower, loose flower and for its aromatic worth in essential oil industry (Padaganur *et al.,* 2005; Alan *et al.,*2007). The flowers are used in wedding ceremonies, garlands, bowl and vase decoration and various traditional rituals (Randhawa and Mukhopadhyay, 1986). It has great demand in the domestic and international market with high remunerative returns. There are many factors which adversely affect the plant growth, flower yield, quality of flower and bulb production of tuberose. The economic yield can be increased manifold with adoption of proper plant nutrition and judicious water management practices. Tuberose is a gross feeder and requires a large quantity of NPK, both in the form of organic and inorganic fertilizers (Singh *et al.,* 1976; Amarjeet and Godara, 1998; Kabir *et al.,* 2011). Mineral fertilizers have great influence on growth, flower and bulb production in tuberose (Mitra *et al.,* 1979; Yadav *et al.,* 1985; Roy, 1992). Optimum irrigation has an important role on plant growth and is essential to increase yield and quality of plants. Deficit irrigation, one of the environmental stresses, is the most significant factor restricting the plant growth, yield components and productivity (Halepyati *et al.,* 1996), whereas irrigating the plants at regular interval increased the growth, flower and bulb yield (Manoly, 2001; EL-Naggar and Byari, 2009).The Indian state of West Bengal occupies the leading position in respect of area and production of tuberose (Biswas *et al.,*2006). However, the information relating to the optimum irrigation level for maximum crop and water productivity is very limited. In view of the above situations in consideration, the present investigation was carried out to determine the effect of different levels of irrigation on growth, yield and water productivity of tuberose in the Indo-Gangetic plain of West Bengal.

Materials and Methods

Location and soil of the experimental site

This experiment was conducted during the growing seasons of 2012 and 2013 at the Departmental Experimental Field of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal lying in between $22^0$56' N latitude and $88^0$32' E longitudes with an elevation of 9.75 m above the mean sea level. The soil of the experimental is Gangetic alluvium (Typic Fluvaquept) with sandy clay loam in texture (31% clay) having 1.48 Mg/m^3 bulk density and 49.1% porosity. The surface soil had 6.8 pH (1:2.5), 0.34 dS/m electrical conductivity, 4.6 g/kg soil organic carbon and 14.3 cmol(+)/kg) cation exchange capacity. The soil was low in available N (132 mg/kg), medium in available P (15.1 mg/kg) and available K (152 mg/kg). The area represents sub-tropical humid climate. The annual precipitation is 1320 mm of which 75-80% is received during June through September. The potential evapo-transpiration is 1024 mm per year. The mean monthly rainfall, maximum and minimum temperature and relative humidity during the plant growth period have been depicted in Figure 1.

There were nine treatments consisted of three irrigation levels based on irrigation water (IW) to cumulative pan evaporation (CPE) ratio (I_1: IW/CPE 0.4, I_2: IW/CPE 0.8, I_3: IW/CPE 1.0) and three tuberose cultivars (V_1: Prajwal, V_2: Calcutta Single, V_3: Calcutta Double) was laid out in a factorial randomized block design (FRBD) with three replications. The net plot size was 1.2 m x 1.0 m leaving 0.5 m bund width and 1.0 m irrigation channel. Well decomposed farm yard manure containing 0.5% N, 0.3% P_2O_5 and 0.5% K_2O on dry weight basis @ 15 t/ha was applied at the time of final land preparation. The recommended doses of 200:200:150 kg/ha of N, P_2O_5 and K_2O were applied as urea, single super phosphate and muriate of potash,

Figure 1. Distribution of rainfall, maximum and minimum temperature during the cropping period

respectively. Full P and K and one-third of N were applied as basal and remaining N was top-dressed in three equal splits at 25, 50 and 75 days after planting. The bulbs of three tuberose cultivars with uniform size (2.5-3.5cm diameter and 15.5-17.7g weight) were planted at a depth of 6 cm in each unit plot during the second week of March in 2012 and 2013. The planting distance was 30 x 30 cm between row to row and plant to plant. The number of bulbs per unit plot was 12. Standard cultural practices were followed uniformly. Five representative plants from the inner rows of each plot were labeled and tagged in each replication and were used for recording of phenological, and yield parameters. Data of plant height, number of leaves per plant, length and diameter of spike at harvest, number of spike per plot, number of florets per spike, length of floret, floret diameter at full open stage, spike, and loose flower yield and bulb yield per were recorded from the sample plants during the course of experiment. Harvesting of flower was completed in several pickings within September and October in each year. Flower longevity (days) was counted from the opening of first floret of spike till the last floret faded in color on each sample plant.

Water requirement of crop was computed using the following water balance equation,

$$WU = P + I + Cp - Dp - Rf \pm \Delta S$$

Where, WU is the total water use (mm), P is the precipitation, Cp is the contribution through capillary rise from ground water, Dpis the deep percolation, Rfis the surface run off and $\pm \Delta S$ is the change in soil water storage in the profile between planting and harvest time (mm). Since the ground water was very deep (5-6 m), Cp was assumed to be negligible. There was no Rf because of low depth of water application and low intensity of rainfall.

$$\text{So, } WU = P + I - Dp \pm \Delta S$$

The irrigation water requirement was computed on the basis CPE, pan factor, crop coefficient and canopy area factor. The pan evaporation data was obtained from a Class A Pan located inside the experimental site on a wooden support at a height of 15 cm above the soil surface and readings were recorded daily.An amount of 30 mm pre-irrigation was applied in all treatments before planting of the bulbs for uniform seedlings emergence and maintenance of soil moisture.

Results and Discussion

Growth characteristics

The application of different irrigation levels had significant effects on growth parameters such as plant height and number of leaves per plant in tuberose (Table 1). The characters consistently increased with increasing moisture regimes. However, the tallest plant with highest number of leaves was obtained with the irrigation schedule at IW/CPE 1.0, which was at par with the irrigation schedule at IW/CPE 0.8. In contrast, significantly the lowest plant growth characters were registered at lower moisture regime of IW/CPE 0.4. These indicate that optimal irrigation had tremendous effects on plant growth and development in tuberose. The corresponding parameters among the varieties under study, irrespective of irrigation treatments, were significantly influenced. However, maximum plant height was recorded by Prajwal variety, followed by Calcutta single and Calcutta double cultivars, respectively. In case of number of leaves per plant, the reverse trend was observed.

The interaction effects between the irrigation schedule and the varieties on these growth parameters were significant. Maximum plant height was recorded by Prajwal variety with irrigation at IW/CPE 1.0, which was competitive with irrigation at IW/CPE 0.8. Conversely, maximum number of leaves per plant was observed by Calcutta double cultivar with irrigation at IW/CPE 1.0 and was at par with irrigation at IW/CPE 0.8. In contrast, shortest plant by Calcutta double and lowest number of leaves per plant by Prajwal was registered with irrigation schedule at IW/CPE 0.4.

Flowering characteristics

The floral characteristics viz., spike length, spike diameter, number of spike per plot, number of florets per spike, length of the floret, floret diameter and vase life of tuberose plant were significantly

Table 1. Effect of different levels of irrigation on growth and spike characteristics of three varieties of tuberose (2-year pooled data)

Treatment	Plant height (cm) Variety				Number of leaves/plant Variety				Spike length (cm) Variety				Spike diameter (cm) Variety				Number of spike/plot Variety			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
I_1	89.8	86.3	82.5	86.2	79.2	98.7	112.4	96.8	65.1	63.5	62.7	63.8	0.81	0.84	0.87	0.84	26.4	31.9	33.5	30.6
I_2	92.5	88.5	86.3	89.1	82.5	106.4	118.9	102.6	67.4	64.8	63.6	65.3	0.86	0.88	0.91	0.88	30.8	32.6	33.4	32.3
I_3	93.7	90.2	88.2	90.7	84.0	109.3	122.1	105.1	68.2	65.2	64.5	66.0	0.88	0.92	0.93	0.91	31.9	32.7	34.8	33.1
Mean	92.0	88.3	85.7	-	81.9	104.8	117.8	-	66.9	64.5	63.6	-	0.85	0.88	0.90	-	29.7	32.4	33.9	-
	I	V	I x V		I	V	I x V		I	V	I x V		I	V	I x V		I	V	I x V	
SEm±	0.42	0.42	0.85		1.32	1.32	2.57		0.38	0.38	0.73		0.01	0.01	0.02		0.51	0.51	0.98	
CD (0.05)	1.25	1.25	2.54		3.96	3.96	7.65		1.14	1.14	2.16		0.03	0.03	0.05		1.52	1.52	2.93	

I_1 = Irrigation at IW/CPE 0.4, I_2 = Irrigation at IW/CPE 0.8, I_3 = Irrigation at IW/CPE 1.0; V_1 = Prajwal, V_2 = Calcutta Single, V_3 = Calcutta Double

affected by the various irrigation schedules (Tables 1 and 2). Maximum flowering attributes were recorded in the irrigation schedule of IW/CPE 1.0 which was statistically at par with irrigation schedule of IW/CPE 0.8. Significantly the lowest floral attributes were observed with irrigation schedule at IW/CPE 0.4. These indicate that optimal irrigation scheduling in the important growth stages is necessary for increasing the floral characteristics. Similarly, the cultivars examined regardless of different irrigation treatments varied were significantly. Maximum values of the spike diameter, spike per plot and floret diameter were shown by Calcutta double, being at par with Calcutta single, but superior to Prajwa. Similarly, the highest values of florets per spike, length of the floret and vase life were recorded by Calcutta double, which were superior to Pralwal, but competitive with Calcutta single. Maximum length of spike was registered by Prajwal, followed by Calcutta single and Calcutta double, respectively.

The interactions between the irrigation schedules and the varieties on these floral parameters were significant. However, maximum variables excepting spike length were noted by Calcutta double with irrigation schedule at IW/CPE 1.0. However, it was at par with irrigation schedule of IW/CPE 0.8, but competitive with Calcutta single at irrigation schedules of IW/CPE 1.0 and IW/CPE 0.8 with some deviations. The variables were least in Prajwal at all irrigation levels excepting the spike length which was found maximum in higher irrigation regimes as compared with lower irrigation regime.

Spike, flower and bulb yields

The yields of spike, loose flower and bulb per hectare of tuberose, irrespective of varieties, were significantly influenced by the application of various levels of irrigation (Table 3). Highest yields of these components were obtained with higher irrigation level at IW/CPE 1.0 which was statistically at par with moderate irrigation level at IW/CPE 0.8. Significantly the lowest values were recorded with lower level of irrigation at IW/CPE 0.4. These results are in conformity with Jaimez *et al.*(2000), Moftah and Al Humaid, (2006) and El Naggar and Byari, (2009) who

TABLE 2. Effects of different levels of irrigation on floral characteristics of three varieties of tuberose (2-year pooled data)

Treatment	Number of florets /spike Variety				Length of the floret (cm) Variety				Floret diameter (cm) Variety				Vase life (days) Variety			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
I_1	29.6	31.5	32.5	31.2	14.3	16.2	14.6	15.0	0.69	0.72	0.74	0.72	13.18	14.32	16.15	14.55
I_2	30.3	31.9	33.5	31.9	15.7	18.1	16.1	16.7	0.73	0.77	0.80	0.77	14.56	15.73	18.13	16.14
I_3	30.8	32.4	34.3	32.5	16.4	19.2	17.1	17.6	0.75	0.78	0.81	0.78	15.67	16.42	19.24	17.11
Mean	30.2	31.9	33.4	-	15.5	17.8	15.9	-	0.72	0.76	0.78	-	14.47	15.49	17.84	-
	I	V	I x V		I	V	I x V		I	V	I x V		I	V	I x V	
SEm±	0.22	0.22	0.43		0.39	0.39	0.76		0.01	0.01	0.02		0.45	0.45	0.87	
CD (0.05)	0.65	0.65	1.28		1.16	1.16	2.27		0.03	0.03	0.05		1.34	1.34	2.60	

I_1 = Irrigation at IW/CPE 0.4, I_2 = Irrigation at IW/CPE 0.8, I_3 = Irrigation at IW/CPE 1.0; V_1 = Prajwal, V_2 = Calcutta Single, V_3 = Calcutta Double

found that water shortage in important phonological stages of plant adversely affected the number of aborted flowers, bulb size, inflorescence length, and number of floral buds. Water deficit also affects negatively the process of flowering in plant by reducing the fertility of newly formed flowers (Slawinska *et al.,* 2001).Similarly, the varieties under scrutiny, irrespective irrigation treatments, also varied significantly. The highest spike, loose flower and bulb yields were observed in Calcutta double, which was at par with Calcutta single. The performance of Prajwal in promotion of spike, flower and bulb yields was significantly the lowest.

The interactions between the irrigation schedules and the varieties on tuberose yields were significant. However, maximum yields were obtained by Calcutta double with an irrigation schedule of IW/CPE 1.0. These were at par with irrigation schedule of IW/CPE 0.8, but competitive with Calcutta single at irrigation schedules of IW/CPE 1.0 and IW/CPE 0.8. The minimum yields were recorded by Prajwal at all irrigation levels, the more so in lower irrigation level than in higher irrigation level.

Water balance components and water productivity

During the plant growing seasons the average contribution of effective rainfall was 797 mm, whereas the figures for soil profile contribution was 14.3 to 19.8 mm. Depth of water applied in irrigation treatments I_1, I_2, and I_3 were 200, 285 and 360 mm, respectively. Thus the seasonal water use by the plant was 1046.8, 1129.2 and 1201.3mm for I_1, I_2, and I_3, respectively (Table 4). It is conspicuous that soil profile moisture contribution was relatively more under deficit irrigation than in full irrigation condition. Maximum water productivity of 8.40kg/ha-mm was observed in lower irrigation level (I_1), followed by that of 8.36 kg/ha-mm at moderate irrigation level (I_2) and minimum of 8.23 kg/ha-mm at higher irrigation level (I_3). The results corroborated with the findings of Hassan and Ali (2013) who reported that the maximum water use efficiency was obtained with the lowest irrigation level, while the minimum with the highest irrigation level. Furthermore, lower water productivity with higher irrigation level could be due to greater loss of water

Table 3. Effect of different levels of irrigation on spike, loose flower and bulb yield of three varieties of tuberose (2- year pooled data)

Treatment	Spike yield ('000/ha) Variety				Loose flower yield (t/ha) Variety				Bulb yield (t/ha) Variety			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
I_1	220.00	265.83	279.17	255.00	7.17	9.21	9.98	8.79	17.18	17.91	18.83	17.97
I_2	256.67	271.67	278.33	268.89	8.56	9.54	10.26	9.45	18.42	20.53	21.64	20.20
I_3	265.83	272.50	290.00	276.11	9.01	9.71	10.94	9.89	19.63	21.12	22.47	21.07
Mean	247.50	270.00	282.50	-	8.24	9.49	10.40	-	18.41	19.85	20.98	19.75
	I	V	I x V		I	V	I x V		I	V	I x V	
SEm±	3.28	3.28	6.41		0.18	0.18	0.35		0.41	0.41	0.79	
CD (5%)	9.83	9.83	19.22		0.54	0.54	1.04		1.24	1.24	2.35	

I_1 = Irrigation at IW/CPE 0.4, I_2 = Irrigation at IW/CPE 0.8, I_3 = Irrigation at IW/CPE 1.0; V_1 = Prajwal, V_2 = Calcutta Single, V_3 = Calcutta Double

Table 4. Seasonal water use and water use efficiency of tuberose plant at varied irrigation level (2-year pooled data)

Treatment	Profile contribution (mm)	Rainfall (mm)	Deep percolation (mm)	Irrigation water (mm)	≠ Seasonal water use (mm)	Flower yield (t/ha)	Water productivity (kg/ha-mm)
I_1	19.8	1319	522	200	1046.8	8.79	8.40
I_2	17.2	1319	522	285	1129.2	9.45	8.36
I_3	14.3	1319	522	360	1201.3	9.89	8.23

I_1 = Irrigation at IW/CPE 0.4, I_2 = Irrigation at IW/CPE 0.8, I_3 = Irrigation at IW/CPE 1.0, Depth of each irrigation @ 40 mm, ≠ 30 mm pre-planting irrigation water added for uniform seedlings emergence

by evapotranspiration than the corresponding increase in flower yield (Kamkar *et al.,* 2011).

Conclusion

It may be inferred that tuberose grown in the Indo-Gangetic plain of West Bengal responded positively to the varied levels of irrigation application. However, irrigation at higher moisture regime of IW/CPE 1.0 significantly increased the growth characteristics, yield attributes and flower yields, which were competitive with moderate irrigation regime of IW/CPE 0.8. The growth, yield attributes and yields of plant were found minimum at lower irrigation regime of IW/CPE 0.4. The cultivar Calcutta double performed better than Calcutta single and Prajwal in promoting growth and yield characteristics and yields at all irrigation levels, the more so in higher moisture regime than in lower moisture regime. However, in consideration of relatively higher crop and water productivity, irrigation schedule at IW/CPE 0.8 with Calcutta double cultivar may be advocated for tuberose cultivators in this region.

Literature Cited

Alan, O., Gunen, Y., Ceylan, S. and Gunen, E. (2007). Effect of nitrogen applications on flower yield, some quality characteristics and leaf mineral content in tuberose (*Polianthes tuberosa* L.). *Anadolu Journal of Aegean Agricultural Research Institute* **17**(1): 43-57.

Amarjeet, S. and Godara, N. R. (1998). Effect of nutritional requirement of tuberose (*Polianthes* *tuberosaI* L) cv. Single on flower yield characters. *Haryana Agricultural University Journal of Research* **28** (1):15-20.

Biswas, G.J., Kumar, P.N. and Bhattacharjee, A.(2006). Tuberose. Published by ICAR, New Delhi, vol 1-2.

De Hertogh, A. and Le Nard, M. (1993). The physiology of flower bulbs. Elsevier Sci. Pub. pp 811.

El Naggar, AI. and Byari, S. H.(2009). Effects of Irrigation frequency regimes and weed control management on field grown tuberoses (*Polianthes Tuberosa*, L.) in the Saudi Arabian western region: 2. Bulb and bulblet's yield, growth and development and grade qualities. *Egyptian Journal of Horticulture* **36** (1): 119-147.

Halepyati, A.S., Sujatha, K.and Prabhakar, M. M.(1996). Growth, yield, water relations and its use in tuberose (*Polianthes tuberosa*) as influenced by irrigation regime and nitrogen level. *Indian Journal of Agricultural Sciences* **65** (12): 866-869.

Hassan, F.A.S. and Ali, E.F. (2014). Impact of different water regimes based on class-A pan on growth, yield and oil content of *Coriandrum sativum* L. plant. *Journal of the Saudi Society of Agricultural Science* **13** (2): 155-161

Jaimez, R.E., Vielma, O., Rada, F. and Garcia N. C. (2000). Effect of water deficient on the dynamics of flowering and fruit production in *Capsicum chinenses* Jacq. in a tropical semiarid region of Venezuela. *Journal of Agronomy and Crop Science* **185**:113-119.

Kabir, A.K.M.R., Iman, M.H., Mondal, M.M.A. and Chowdhury, S.(2011). Response of tuberose to integrated nutrient management. *Journal of Environmental Science and Natural Resources* **4** (2): 55-59.

Kamkar, B., Daneshmandb, A.R., Ghooshchic, F., Shiraniradd, A.H. and Safahani, A.R.(2011). The effects of irrigation regimes and nitrogen rates on some agronomic traits of canola under a semiarid environment. *Agricultural Water Management* **98**:1005–1012.

Manoly, N.D. (2001). Effect of irrigation interval and bulb size on *Polianthes tuberosa* L. The fifth Arabian Hort. Conf., Ismailia, Egypt. March 24-28.

Mitra, S.N., Munshi, P.S.and Roy, S. (1979). Effects of different levels of nitrogen and bulb size on growth and flowering of tuberose (*Polianthes tuberose* L.). *Indian Agric*., **23** (3): 185-188.

Moftah, A.E.and Al Humaid, A.I. (2006). Response of vegetative and reproductive parameters of water stressed tuberose plant to vapor grad and kaolin anti transpirants. *Journal King Saud UniversityAgriculture Science* **18:** 127–139.

Padaganur, V.G., Mokashi, A.N. and Patil, V.S.(2005). Flowering, flower quality and yield of tuberose as influenced by vermicompost, farmyard manure and cowdung, *Karnataka Journal Agricultural Science* **18**: 729-734.

Patel, M.M., Parmar, P.B. and Parmar, B.R. (2006). Effect of nitrogen, phosphorus and spacing on growth and flowering in tuberose (*Polianthes tuberose* L.) cv. Single. *Indian Journal Ornamental Horticulture* **9** (4): 286-289.

Randhawa, G. S. and Mukhopadhyay, A. (1986). Tuberose. In: Floriculture in India. Allied pub. Pvt. Ltd., New Delhi. pp. 425-426.

Roy, U. (1992). Effect of inorganic nitrogen and potash on growth, bulb and flower production in tuberose (*Polianthes tuberose* L.). M.Sc. (Ag.) thesis, Dept. of Hort, BAU, Mymonsingh.

Singh, R.S., Motial, V.S. and Singh, L.B. (1976). Effect of nitrogen, phosphorus and patash fertilizer on tuberose (*Polianthes tuberose* L.). *Indian Journal Horticulture* **33** (3-4): 289-294.

Slawinska, J. and Obendorf, R.L.(2001). Buckwheat seed set in plant and during *in vitro* inflorescence culture: Evaluation of temperature and water deficient stress. *Seed Science Research* **11:** 223–233.

Yadav, L.P. Bose, T.K.and Maity, R.G. (1985). Response of tuberose (*Polianthes tubersa* L.) to nitrogen and phosphorus fertilization. *Progressive Horticulture* **17** (2): 83-86.

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Study of Physical and Biochemical Grain Quality Parameters in Rice (*Oryza Sativa* L.) Genotypes for Submergence Tolerance

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Abstract

The appearance of milled rice is important to the consumers. Thus grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production. The cooking properties of rice are largely dependent on the chemical composition of cultivars. The objective of the present investigation was to study the grain quality parameters in rice genotypes for submergence tolerance breeding programme for selection as good promise to introduce in low land submergence prone field location. The experimental material consist of selected five paddy genotypes such as Mahananda, Purnendu, Nagalmuda, Lakshmikajal and Jaladhi II, selected high yielding submergence tolerant F_2 lines and selected six herbal treated seeds of paddy genotypes. The samples were prepared as per the standard procedure of each quality parameter and data were collected for three replications of each sample in each of the quality parameter. Physical quality traits includes kernel length (mm), kernel breadth (mm), L/B ratio, grain type, hulling % and chemical quality traits includes ASV value, gelatinization temp, protein %, amylose %, iron (mg).

All the selected five paddy genotypes, selected high yielding submergence tolerant F_2 lines and selected herbal treated seeds of paddy genotypes were analysed for physical and biochemical qualities including protein and iron content. When they were further tallies with their seed yield performances under submerged field condition, four promising selections were ultimately achieved which not only have given very high seed yield performances but also have very supreme grain quality features in respect of physical and biochemical quality with alleviate level of protein and iron content. Finally it was observed that two paddy genotypes namely Mahananda and Purnendu and two F_2 individuals recorded high seed yield along with appreciable amount of protein, amylose and iron content. So this would offer a good promise to introduce these selections to the future breeding programme for the development of submergence tolerance in paddy.

Key words: Quality parameters, rice, submergence, promising selections

Introduction

Rice is known as the grain of life and is synonymous with food for Asians as it supplies majority of starch, protein and micronutrient requirements (Juliano, 1985; Qiu, 1992; Donald, 2002). According to Ahuja *et al*., (2008) rice is described as functional food. Rice is grown in many countries all over the world and in addition to its social importance it plays an important role in human nutrition as well as in agricultural economics. Nowadays, consumers are very concerned with milling and cooking quality. Today, there are a large number of varieties and more are being developed to enhance agronomic and technological quality in order to meet consumer demands (Garcia *et al*., 2011). In fact, rice is the most important crop for the people living in Asia where it has a long history of cultivation and is deeply ingrained in the daily lives of Asian people (Narayan *et al*., 2000). Nutrition is one of the most significant factors facing the developing world. In India, over 50% of all children receive insufficient calories every day to meet their potential growth and development requirements (Mahendra *et al.*, 2004). Therefore, developing nutritionally enriched staple plant foods through plant breeding methods holds a great promise for sustainable food based solutions (Banzinger and Long, 2000). Cooking and eating characteristics of rice are determined by a combination of objective and subjective methods. The appearance of milled rice is important to the consumers. Thus grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production (Adair *et al.*, 1966). The cooking properties of rice are largely dependent on the chemical composition of cultivars (Mohapatra & Bal, 2006). Many of the cooking and eating characteristics of milled rice are influence by the ratio of two kinds of starch; amylose and amylopectin in the rice grain (Rao *et al.*, 1952). Starch is a polymer of glucose and amylose is a linear polymer of glucose. Amylose content has been considered one of the most important characteristics in cooking behavior (Xie *et al.*, 2007). The time required for cooking milled rice is determined by gelatinization temperature or GT. An estimate of the gelatinization temperature is indexed by the alkali digestibility test (Little *et al.*, 1958). GT of milled rice is evaluated by determining the alkali spreading value. In many rice-growing countries, there is a distinct preference for rice with intermediate gelatinization temperature. Amylose content of milled rice is determined by using the colorimetric iodine assay index method. Mostly the rice varieties with higher GT may have low amylose content (AC) (Jennings *et al.*, 1979). The most important quality criterions based on chemical characteristics are crude protein and ash contents (Lasztity, 1999). It is evident that the amount of protein in rice is not very high but the quality of rice protein is far better than other cereals (James and McCaskill, 1983; Janick, 2002). Araullo *et al.*, (1976) and Awan (1996) stated that rice consists of about 7% to 8% protein. The human body also requires trace minerals including iron. Mostly the iron is present in the form of hemoglobin in human body. The mineral composition may be affected by the environmental and area locations (Bajaj, 1991). Watts (1980) reported about 17 ppm iron mineral contents in 12 samples of Canadian wild rice. According to Juliano and Duff (1991) grain quality is second only to yield as the major breeding objective. In the future, grain quality will be even more important as once the very poor, many of whom depend largely on rice for their staple food become better off and begin to demand higher quality rice (Welch and Graham, 2002). The extent of water absorbed by rice during cooking is considered an economic quality as it gives an estimate of the volume increase during cooking and water uptake shows a positive significant influence on grain elongation (Sood and Saddiq, 1986).

Submergence has been identified as the 3rd most important constraints affecting rice production in Eastern India (Hossain and Laborte, 1996). About 29% of Indias total rice area (approximately 13 million hectare) is rainfed low land and this area is prone to unscheduled submergence of the rice crop (Sarkar *et al.*, 2006, Maurya *et al.*, 1988). Nearly 25% of the world's rice is cultivated in the rainfed lowland ecosystem which accounts for only 17% of the global rice supply (Mohanty *et al.*, 2000). On the above ground the present investigation was to identify the some physical and biochemical grain quality parameters in some selected rice genotypes which performed better in submerged condition.

Materials and Methods

The experimental material consist of selected five paddy genotypes such as Mahananda, Purnendu, Nagalmuda,Lakshmikajal and Jaladhi II, selected high yielding submergence tolerant F_2 lines and selected dry herbal treated seeds of paddy genotypes which performed better under low land submerged condition in the Calcutta University Experimental Farm at Baruipur, 24 Parganas (S), West Bengal, India in the kharif season of 2011, 2012 and 2013 years with water depth at least 50 cm for two weeks at the vegetative stage of the crop. The laboratory experiment of quality parameters along with cooking parameters were done at Department of Genetics and Plant Breeding, University of Calcutta during the years. The samples were prepared as per the procedure of each quality parameter given below and data were collected for three replications of each sample in each of the quality parameter.

Physical Traits:

1. Hulling percentage: 100gm of grains of each sample of each genotype was subjected to de-husking in a de-husker. The de-husked kernels were weighed and Hulling percentage is determined by the following :

$$\text{Hulling \%} = \frac{\text{Weight of the de-husked kernel}}{\text{Weight of a paddy}} \text{X } 100$$

2. Kernel length: Five randomly selected full grains of each genotype were at first de-husked and then their lengths were measured by thickness gauge micrometer.

3. Kernel breadth: The grains which were taken for measuring length, their breadth were also measured at the same time by the same instrument.

4. Length/ breadth (L/B) ratio: Length was divided by breadth.

On the basis of average length of kernels, milled rice is classified into following:

Scale	Size	Length (mm)
1	Extra-long (EL)	>7.50
3	Long (L)	6.61 – 7.50
5	Medium (M)	5.51 – 6.60
7	Short (S)	5.50 or less

Grain shape is estimated by length / breath ratio of kernels

Scale	Size shape	L / B ratio
1	Slender (S)	Over 3
3	Medium (M)	2.1 – 3.0
5	Bold (B)	1.1 – 2.0
9	Round (R)	1.0 or less

Chemical traits:

1. Determination of amylose was done as per the standard procedure of Sadasivam and Manickam, 1996 and standard analytical method of Juliano, 1971**.**

Standard analytical methods for estimating amylose content (Juliano, 1971)

Grain type	Range of Amylose (%)
Waxy	0-8
Non-waxy	
· Low Amylose content	8-20
· Intermediate Amylose content	20-25
· High Amylose content	25-32

2. Determination alkali spreading value and gelatinization temperature was done as per the standard procedure of Perez and Juliano, 1978.

Gelatinization temperature

Classification	Rating	Gelatinization temperature
1 – 3	Low	High > 74^0C
3 – 5	Low	
	Intermediate	High intermediate ($71 - 74^0$C)
5 – 7	Intermediate	Intermediate (70^0C - 74^0C)
> 7	High	Low (55 to 69^0C)

3. Protein estimation was done by Lowry's (1951) method

4. Estimation of total iron was done as per the procedure of Adachi *et al.*, 2006

Cooking quality:

Volume expansion ratio was done as per the procedure of Juliano *et al.*, 1965.

Results and Discussion

Quality parameter of the five paddy genotypes:

The quality aspect of Kernel length (L), Kernel breadth (B), L/B ratio, Hulling %, Volume Expansion, Alkali Spreading Value(ASV), Gelatinization temperature (GT), Protein, Amylose and Iron content of the five submergence tolerant genotypes and the tolerant check paddy genotypes was studied (Table 1)

It was observed from the Table 1 that the medium kernel length was recorded for the tolerant check variety, FR13A. Based on the kernel length and the L/B ratio the grain type was estimated. Among the five rice genotype Mahananda exhibited highest kernel length (7.79mm) followed by Nagalmuda (6.28mm). Maximum hulling percentage was for Mahananda (76.61%) followed by Nangalmuda. Based on the kernel length and L/B ratio the grain type was estimated. Among the five rice genotypes Mahananda was extra long slender, Purnendu was short medium, Lakshmikajal was short medium, Nagalmuda was medium slender and Jaladhi II was short medium. The hulling% was highest for Mahananda (77.86%). High ASV and intermediate GT (Fig 1) was performed by Purnendu. Mahananda, Lakshmikajal, Nagalmuda and Jaladhi II performed moderate ASV and high intermediate GT. Protein % ranges from 4.8% to 6.48%. High protein% i.e. more than 5% was performed by Mahananda, Lakshmikajal, Purnendu and Nagalmuda. Lakshmikajal exhibited highest amount of protein%. Amylose content (AC) was ranged from 19.00% to 23.40%. Highest level of AC was recorded in for Jaladhi II followed by Lakshmikajal. Intermediate amylose content determines the consumer preferences for cooked rice. The iron content was high for Purnendu (0.97 mg) followed by Mahananda (0.80mg) respectively. The highest volume expansion ratio was shown by Mahananda (2.78).

Quality parameters of the selected high yielding F_2 lines:

The quality aspects of the selected high yielding F_2 lines were recorded in Table 2. For the cross Mahananda x Nagalmuda, the first line exhibited higher kernel length than both of their parents. The first line also showed higher kernel breadth over both of the parents. Regarding the L/B ratio both the F_2 lines showed better performances over their parents. The high ASV with high intermediate GT was performed by both the lines. Protein% was better shown by both the lines over their parents. Both the lines exhibited intermediate AC content with slight higher value than that of their parents. Both the lines showed better iron content over their control but second line performed highest iron content. The first line exhibited better volume expansion than their both of the parents. In cross, Nagalmuda x Purnendu both the lines exhibited higher kernel length over their parents. L/B ratio was higher for the two lines over their parents. The second line exhibited highest L/B ratio. The hulling% was higher in the two lines over their two parents. The GT was high intermediate for both the lines. The protein% was higher for both the two lines over the control. Both the two lines showed intermediate amylose content. The volume expansion ratio was higher for both the lines over their two parents.

In cross, three, Lakshmikajal x Purnendu, both the two lines exhibited higher kernel length over their parents. The first line showed higher kernel breadth over their parents. The second line showed highest L/B ratio. The first line showed highest hulling% over their parents. The ASV was moderate and GT was intermediate for the second line. The first line showed highest protein% i.e. 6.8 over both the parents. Both the two lines showed higher volume expansion than their parents. In cross four, Mahananda x Sonom, the only line performed satisfactorily over the parents lower than the Mahananda (Control). Hulling % was higher for the line over both of the parents. The line showed high intermediates GT. The protein % was higher than that of both parents.

Quality parameter of treated seeds of Mahananda and Swarna which performed better:

The grain quality aspect of six selected treated individuals of Mahannada and Swarna was studied (Table 3). It was observed from the table, for both the genotypes the treatments like neem, tobacco and kalmegh, the kernel length was consequently high over both of the parents. Kalmegh showed highest L/B ratio for the variety Mahananda over the control. In both varieties the treatment neem leaf exhibited highest hulling% over their parents. In Mahananda the three herbal treatments exhibited high intermediate GT. The protein content was high for neem leaf in both the varieties. The iron content was higher for neem leaf followed by tobacco in the two varieties over their

TABLE 1. Grain quality aspects of the selected submergence tolerant genotypes with tolerant checks

Genotype	Physical Traits					Chemical Traits					Cooking Quality
	Kernel Length (mm)	Kernel Breadth (mm)	L/B Ratio	Hulling %	Grain Type	ASV Value	GT	Protein %	Amylose %	Iron %	Volume Expansion
Mahananda	7.79	2.05	3.79	77.86	ELS	4.83	High Intermediate	5.16	19.00	0.80	2.78
Purnendu	5.40	2.13	2.54	68.00	SM	6.75	Intermediate	5.10	22.6	0.97	2.25
Lakshmikajal	5.17	1.92	2.69	65.50	SM	3.46	High Intermediate	6.48	23.00	0.47	2.50
Nangalmuda	6.28	2.03	3.09	68.00	MS	3.73	High Intermediate	5.82	20.40	0.70	2.43
Jaladhi II	5.54	2.42	2.28	67.66	SM	4.3	High Intermediate	4.8	23.40	0.21	2.05
FR13A (TC)	5.78	2.41	2.61	70.00	LM	3.98	High	6.44	20.5	0.71	2.95
Swarna sub1(TC)	5.25	2.03	2.58	67.00	SM	2.23	High	5.3	14.6	0.46	2.93
CD	0.2595	0.0886	0.2643	1.4987	-	0.1454	-	0.1746	0.228	0.130	0.1047

TC-Tolerant check

TABLE 2. Grain quality aspects of the selected submergence tolerant F_2 lines

Cross		Line no.	Physical Traits					Chemical Traits					Cooking Quality
			Kernel Length (mm)	Kernel Breadth (mm)	L/B Ratio	Grain Type	Hulling %	ASV Value	Gelatinization Temp	Protein %	Amylose %	Iron (mg)	Volume Expansion ratio
Mahananda	Nagalmuda	C1L2P5	8.10	2.10	3.86	ELS	73.66	4.95	High Intermediate	6.00	21.00	0.72	2.85
		C1L4P7	7.22	1.85	3.90	LS	76.67	5.00	High Intermediate	5.88	22.20	0.92	2.55
Nagalmuda	Purnendu	C2L1P4	7.33	2.12	3.45	LS	70.67	4.52	High Intermediate	5.87	23.50	0.78	2.82
		C2L4P6	6.82	1.87	3.65	LS	72.00	4.30	High Intermediate	5.85	21.5	0.73	2.54
Lakshmi kajal	Purnendu	C3L3P5	5.85	2.20	2.65	MM	70.67	4.89	High Intermediate	6.80	24.50	0.86	2.65
		C3L7P6	6.00	1.99	3.01	MS	68.66	5.00	Intermediate	5.60	23.40	0.71	2.52
Mahananda	Sonom	C4L4P5	7.72	2.10	3.67	ELS	76.50	4.88	High Intermediate	6.10	22.40	0.75	2.75
Mahananda (Control)			7.79	2.05	3.79	ELS	77.86	4.83	High Intermediate	5.16	19.00	0.80	2.78
Nagalmuda (Control)			6.28	2.03	3.09	MS	68.00	3.73	High Intermediate	5.82	20.40	0.70	2.43
Purnendu (Control)			5.40	2.13	2.54	SM	68.00	6.75	Intermediate	5.10	22.6	0.97	2.25
Lakshmikajal (Control)			5.17	1.92	2.69	SM	65.50	3.46	High Intermediate	6.48	23.00	0.47	2.50
Sonom (Control)			5.45	2.01	2.71	SM	62.00	2.25	High	5.12	16.50	0.42	2.95
CD			0.011	0.007	0.008	-	0.533	0.009	-	0.042	0.365	0.021	0.065

control. It can be say that neem and tobacco leaf performs satisfactorily over their control.

The promising selection for high productive and good quality under submerged condition:

The promising selection for high productive and good productive under submergence condition were presented in the Table 4 and Fig 1. Mahananda and Purnendu were the two selected from the studied genotypes based on all characters. As these two genotypes have recorded high seed yield per plant 40.5g and 31.0 g and even they have very high in hulling%, ASV, protein%, amylose% and iron content quality parameters. Two individual developed from hybridization were selected on hulling%, ASV, protein%, amylose% and iron content quality

1-3= Swarna sub 1, 4-6= Sonom, 7= Mahananda, 8= Lakshmikajal, 9= Jaladhi II, 10= Nagalmuda, 11= Purnendu, 12= C3L7P6, 13= FR13A, 14-15= C1L2P5, 16-17= C1L4P7, 18= C3L3P5

Fig. 1 Alkali spreading value (ASV) estimation of selected paddy genotypes and lines

TABLE 3. Grain quality aspects of the different paddy genotypes with herbal seed treatments

Genotypes	Treatments	Physical Traits					Chemical Traits					Cooking Quality
		Kernel Length (mm)	Kernel Breadth (mm)	L/B Ratio	Grain Type	Hulling %	ASV Value	Gelatini-zation Temp	Protein %	Amylose %	Iron (mg)	Volume\ Expansion ratio
Mahananda	Control	7.79	2.05	3.79	ELS	77.86	4.83	High Intermediate	5.16	19.00	0.80	2.78
	Tobacco	8.12	2.25	3.61	ELS	80.21	5.00	High Intermediate	5.96	21.20	0.91	2.85
	Kalmegh	8.05	2.12	3.80	ELS	79.20	4.95	High Intermediate	5.64	20.50	0.83	2.80
	Neem leaf	8.23	2.32	3.55	ELS	82.54	5.10	High Intermediate	6.0	22.31	0.97	2.88
	CD	0.010	0.009	0.021		0.532	0.032		0.051	0.320	0.021	0.042
Swarna(SC)	Control	5.34	2.0	2.66	SM	61.50	1.98	High	4.84	13.2	0.64	3.25
	Tobacco	5.56	2.18	2.55	MM	63.33	2.38	High	5.04	14.6	0.71	3.52
	Kalmegh	5.44	2.48	2.19	SM	63.20	1.93	High	5.16	14.3	0.68	3.40
	Neem leaf	5.86	2.54	2.31	MM	66.67	2.50	High	5.52	15.2	0.72	3.63
	CD	0.008	0.008	0.003	-	0.321	0.007	-	0.041	0.343	0.021	0.013

SC-Susceptible check

TABLE 4. The promising selections for high productive and good quality under submerged condition

Selected	Physical Traits					Chemical Traits					Cooking Quality	Seed yield /plant (g)
Genotypes	Kernel Length (mm)	Kernel Breadth (mm)	L/B Ratio	Grain Type	Hulling %	ASV Value	Gelatinization Temp	Protein %	Amylose %	Iron (mg)	Volume Expansion ratio	
Mahananda	7.79	2.05	3.79	ELS	77.86	4.83	High Intermediate	5.16	19.00	0.80	2.78	40.5
Purnendu	5.40	2.13	2.54	SM	68.00	6.75	Intermediate	5.10	22.6	0.97	2.25	31.0
C1L2P5	8.10	2.10	3.86	ELS	73.66	4.95	High Intermediate	6.00	21.00	0.72	2.85	46.2
C1L4P7	7.22	1.85	3.90	LS	76.67	5.00	High Intermediate	5.88	22.20	0.92	2.55	47.5

parameters quality parameter and seed yield 46.2 g and 47.5 g respectively. So this would offer a good promise to introduce these selections to the future breeding programme for the development of submergence tolerance in paddy. These would add an extra benefit for incorporating quality parameters into the submergence tolerance paddy genotypes.

Conclusion

The appearance of milled rice is important to the consumers. Thus grain size and shape are the most important criteria of rice quality that breeders consider in developing new varieties for release for commercial production. The cooking properties of rice cultivars are largely dependent on the chemical composition of rice grains. Amylose content and geltanization temperature has been considered one of the most important characteristics in cooking behavior. In many rice growing countries, there is a distinct preference for rice with intermediate gelatinization temperature. In the future, grain quality will be even more important as once the very poor, many of whom depend largely on rice for their staple food become better off and begin to demand higher quality rice. The protein content is affected by environmental conditions. It is evident that the amount of protein in rice is not very high but the quality of rice protein is far better than other cereals. Iron is also an essential constituent for so many enzymes to perform their function especially for the breakdown of glucose and fatty acids to release energy. All the selected five paddy genotypes, selected high yielding submergence tolerant F_2 lines and selected herbal treated seeds of paddy genotypes were analysed for physical and biochemical qualities including protein and iron content. When they were further tallies with their seed yield performances, four promising selections were ultimately achieved which not only have given very high seed yield performances but also have very supreme grain quality features in respect of physical and biochemical quality with alleviate level of protein and iron content. So this would offer a good promise to introduce these selections to the future breeding programme for the development of submergence tolerance in paddy.

Literature Cited

Adachi, A., Morita, K., and Okano, T. 2006. Efficiency of Rice Bran for the Removal of Fe3+ from Solution. *Journal of Health Science*. **52(4):** 455-458

Adair, C.R., Beachell, H.M. and Jodon, N.E. 1966. Rice breeding and testing methods in the U.S. In U.S. Dept. of Agric. Rice in the U.S.: Varieties and production. *USDA Agr. Res. Serv. Handbook*. **289**: 19-64

Ahuja, U., Ahuja, S.C., Thakrar, R. and Singh, R.K. 2008. "Rice – A Nutraceutical", *Asian Agri – History*. **12 (2):** 93-108

Araullo, A.V., De-Padua, D.B. and Graham, M. 1976. Moisture. Rice: Post Harvest Technology. Intr. Develop. Res. Cen. *Ottawa Canada*. 113-118

Awan, I.A. 1996. Physical and biochemical characterization of some of the Pakiatani rice varieties. M.Sc. (Hons.) *Thesis. Dept. of Food Tech., Univ. Agric. Fsd*

Bajaj, Y.P.S. 1991. Wheat. Volume 111, Narosa Pub. Springer Verlag, New York.

Banzinger, M., and Long, J. 2000. The potential for increasing the iron and zinc density of maize through plant - breeding. *FoodNutr. Bull*. **21 (3):** 97-400

Donald, K. 2002. "The importance of Rice". *Science*. **296**: 13

Garcia, D.M., Bassinello, P.Z., Ascheri D.R.M., Ascheri, J.L.R., Trovo, J.B. and Cobucci, R.M.A. 2011. Cooking quality of upland and lowland rice characterized by different methods. *Ciênc. Tecnol. Aliment, Campinas*. **31(2)**: 341-348

Hossain, M. and Laborte, A. 1996. Differential growth in rice production in eastern India: agro ecological and socio-economic constraints. *Physiology of Stress Tolerance of Rice, NDUAT and IRRI, Los Banos, The Philippine*. 221–239

James, C. and McCaskill, D. 1983. Rice in American diet. *Cereal Foods World*. **28(11):** 667-669

Janick, J. 2002. Rice: the natural history of rice. Online available at. http://www.hort.purdue.edu/newcrop/tropical/lecture_20/rice.html

Jennings, P.R., Coffman, W.R. and Kauffman, H.E. 1979. Grain quality In, Rice Improvement. International Rice Research Institute, Manila, Phillippines. 101-119

Juliano, B.O. 1971. A simplified assay for milled rice amylose. *Cereal Sci. Today*. **16**: 334-340

Juliano, B. O. and Duff, B. 1991. Rice grain quality as an emerging priority in national breeding programs, In Rice Grain Marketing and Quality Issues, International Rice Research Institute, Los Banos, Philippines. 55-64

Juliano, B. O. 1985. Criteria and tests for rice grain qualities, In: Rice Chemistry and Technology, 2nd ed. *American Association of Cereal Chemists*. 443 – 524

Juliano, B.O., Onate, L.U. and Deb Mundo, A.M. 1965. Relations of starch composition, protein content and gelatinization temperature to the cooking and eating quality of milled rice. *Food Technol*. **19(12)**: 1006-1011

Lasztity, R. 1999. Cereal Chemistry. Akademia; kiado, Budapest

Little, R.R., Hilder, G.B. and Dawson, E.H. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chem.* **35**: 111–126

Lowry, O.H., Rosebrough, N. J. Farr, A. L. and Randall, R.J. 1951. Protein measurement with the folin phenol reagent. *J Biol Chem.* **193(1)**: 265-75

Mahendra, S., Ravi, C., Viswanathan, B., Gulati, A. and Ramchander, S. 2004. Economic liberalization, programs and household food security: A case study of India IFPRI. Markets, Trade and Industry (MTI) Discussion paper No.68

Maurya, D.M., Bottrall, A. and Farrington, J. 1988. Improved livelihoods, genetic diversity and farmer participation: a strategy for rice breeding in rainfed areas of India. *Experimental Agriculture*. **24**: 311–320

Mohanty, H. K., Mallik, S. and Grover, A. 2000. Prospects of improving flooding tolerance in lowland rice varieties by conventional breeding and genetic engineering. *Curr. Sci*. **78**: 132–137

Mohapatra, D. and Bal, S. 2006. Cooking quality and instrumental textural attributes of cooked rice for different milling fractions. *Journal of Food Engineering*. **73**: 253-259

Narayan, D., Chambers, R., Shah, M.K. & Petesch, P. 2000. Voices of the poor crying out for change. United States of America: Oxford University Press, Inc.

Perez, C. M., and Juliano. B. O. 1978. Modification of the simplified amylose test for milled rice. *Staerke*. **30**: 424-426

Qiu, L.C. 1992. Exploitation and utilization of better quality germplasm resources for increasing human health, In: Annual Report of Chinese Rice Science. *Agricultural Science and Technology Press, Beijing, China*. 1-4

Rao, S.B., Vasudeva, A.R. and Subrahmanya, R.S. 1952. The amylase and amylopectin content of rice and their influence on the cooking quality of cereals. *Proc. Indian Acad. Sci.* **368**: 70-80

Sadasivam, S. and Manickam, A. 1996. Biochemical Methods (2nd Edition). New Age International (P) Limited Publishers, UK, pp 56-57.

Sarkar, R.K., Reddy, J.N., Sharma, S.G. and Ismail, A.M. (2006). Physiological basis of submergence tolerance in rice and implications for crop improvement. Curr Sci. **91**: 899–6

Sood, B. C. and Saddiq, N. 1986. "Current status and future outlook for hybrid rice technology in India", In: Hybrid Rice Technology, Directorate of Rice Research, and Hyderabad. 1-26

Watts, B.M. 1980. Chemical and physico-chemical studies of wild rice. Dissertation Abstracts International. B 41(3): 880. (FSTA 13: 7M 773, 1981)

Welch, R. M. and Graham, R. D. 2002. Breeding crops for enhanced micronutrient content. *Plant and Soil*. **245**: 205-214

Xie, L. *et al.* 2007. Impact of proteins on pasting and cooking properties of waxy and non-waxy rice. *Journal of Cereal Science*. **47(2)**: 372-379

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Micropropagation of Commercially Feasible Foliage Ornamental Plants

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Abstract

Micro propagation a modern plant tissue culture tool, aids to overcome the hindrances of mainstream modus operandi of foliage plant's proliferation to obtain true-to-type progeny plantlets rapidly. The present investigation was conducted at Agri-Horticultural Society of India, Kolkata employing nodal sections and leaf explants of *Syngonium podophyllum* Schott. and *Anthurium crystallinum* Linden and André formulated being cut into 2 to 3 pieces of 6 to 8 mm. length. Explants were surface sterilized by 70 percent (%) ethanol for 1 minute followed by a treatment of 20 minutes by 2% sodium hypochlorite (v/v) and finally rinsed for 5 times by autoclaved water. These explants were stationed in culture tubes holding 20 ml. of Murashige and Skoog medium supplemented with cytokinin and benzyladenine (BA) @ 1, 2, 3 mg/l and auxin and naphthalene acetic acid (NAA) @ 0.1, 0.5 mg/l to verify the best treatment. The sequel of interaction of BA @ 2 mg/l with NAA @ 0.1 and 0.5 mg/l both on regeneration and multiplication of nodal explants of *Syngonium* sp. were noteworthy being manifested 83.30 and 87.5% of explants establishment and shoot protrusion within least number of days of 30.4 and 25.2 respectively. But *Anthurium* sp. become incompetent to form any callus even at 90 days observation although scouring by autoclaved water containing an ampicillin 500 mg capsule eventually retarded the contamination rate only. Hence, it is inferred that in *Syngonium podophyllum* presence of cytokinin (BA) is essential along with divergent levels of auxins in basic culture media for successful regeneration of shoots.

Key words: Foliage, micro propagation, explants, culture media, phytohormones.

Introduction

Floriculture is now emerging as an important and innovative venture in India and the international market. Many kinds of ornamental plant and flowers are grown for domestic and international trade (Ramphal, 1993). Tropical foliage plants are ranked high in the foliage plant industry for their captivating form, color exhibited in the foliage, freshness of leaves and or stems substantive in texture with furnished sprays not prone to rapid wilting and long lasting in flower arrangement as well as when used as potted plants for interior scape or exterior plant scaping. While post harvest life of cut foliages are important, keeping quality criteria in interior for potted plants are marked with quality levels in the live plants industry. Foliages of many attractive tropical plants could be used as cut foliage which includes leather leaf fern (*Rumohra adiantiformis*), Asparagus, *Aspidistra elatior* (cast iron plant), *Nephrolepis exaltata* etc and also more woody ornamentals (Bhattacharjee, 2007). Several scientists also evaluated the suitability of 27 different foliage plant species which could be potentially used as cut foliage (Sindhu *et al.,* 2005). Among the live plants in the industry *Dieffenbachia, Draceana, Ficus, Philodendron, Aglaonema, Cordyline, Syngonium, Anthurium, Scgefflera, Bromeliads, Spathiphyllum,* Palms etc are important for both domestic use as well as for export (Swarup, 1993). The live plants exported to other countries like Europe and Gulf-countries include rooted and unrooted cuttings, large 'finished plants' and 'semifinished' plants. However, export of 'finished' and 'semifinished' plants harbor various problems like acclimatization before transporting as well as plant quarantine clearance. In this respect, the tissue cultured plants with better rooting, superior quality, uniformity and disease free have proven to be advantageous. Tissue culture is very much encouraging in case of non woody plants considering economic aspect and time to attain marketable size.

A large number of aroids are foliage ornamental plants are used as potted plants in interior and exterior plant scaping. Here, an attempt has been taken for micro propagation of two aroids which has large use in floriculture industry. *Syngonium podophyllum* belongs to Aeraceae family have good demand in the export market. This plant generally propagated through stem tip or leaf bud cutting, but for mass propagation tissue culture method is advantageous. It was reported that successful micro propagation through shoot tip axillary buds or nodes as explants was possible (Kozak and Debski, 2009). More recently it was delineated that effective multiplication through internodal segments was also feasible (Rajeevan *et al.,* 2002). Most studies were made with Murashige and Skoog (MS) media supplemented with cytokinin. So far studies made with *Anthurium crystallinum* by different workers ultimately revealed that the conventional method of propagation is through suckers but suckering is very slow which leads to difficulty in mass propagation, hence micro propagation was attempted (Mahanta and Paswan, 2001); (Dhananjaya and Sulladmath, 2008). Here, the present investigation was carried out by using nodal sections and leaf explants in MS media supplemented with different combination of benzyladenine (BA) and naphthalene acetic acid (NAA) to find out best treatment for successful regeneration of shoots.

Materials and Methods

The experiment was orchestrated at the Agri-Horticultural society of India, Kolkata. Two commercially valued ornamental foliage plants viz. *Syngonium podophyllum* Schott. and *Anthurium crystallinum* Linden and André. were contemplated for this study of micro propagation. The former one is of climbing type with its green, variegated, heart shaped leaves, propagated through stem tip or leaf bud cutting whereas the later one produce heart shaped leaves of 40-50 cm. long with metallic violet leaf color at young stage which later turns dark green with white streaks along the veining of the dorsal surface and are extremely decorative. Nodal segments and basal portion of unfolded leaves collected from young stock plants grown in green house of society's garden were employed as explants of *Syngonium podophyllum* and *Anthurium crystallinum* respectively.

All the explants were washed in running water followed by dipping in detergent water for 10 minutes and again washed in running water. Next materials were further scoured in autoclaved distilled water. Then they immersed in 70% ethanol for 1 minutes followed by a treatment of 20 minutes in Sodium hypochlorite 2% (v/v) and explants were then rinsed 5 times by autoclaved distilled water to remove any trace of sodium hypochlorite. Both these explants were formulated being cut them into 2-3 pieces of 6-8 mm. length. Surface washing of *Anthurium crystallinum*'s explants by 100ml. autoclaved distilled water containing 1 dissolved 500mg. ampicillin capsule was performed as an extra precautionary means. Finally all explants were soaked by a sterilized blotting paper for removal of extra water. After that the concocted explants were stationed in a culture bottle (50 ml.) holding 20 ml. of Murashige and Skoog (MS) medium supplemented with combination of three concentrations of Benzyladenine (BA) @ 1, 2, 3 mg/l and two levels of Naphthalene acetic acid (NAA) @ 0.1, 0.5 mg/l, gelled with 8% (w/v) agar. Three treatments were kept as control where Auxin i.e NAA was unemployed. The pH of the medium was adjusted to 5.8 before autoclaving the media at 120^{0}C for 15 minutes. The culture was incubated at 25^{0}C±2^{0}C and light of 16 hours with intensity of 1.5 K. Lux at plant level provided by florescent lamps and 8 hours dark photoperiods. Humidity of 65% was maintained at the culture room. The culture bottle with four explants in each bottle were kept for 30 days if emergence of greening followed by shoot appearance with leaves were observed, a second and third 30 days re-culture on the same culture medium were also carried out in case of *Syngonium podophyllum*. Apart from, when a sign of contamination noted specially in case of *Anthurium crystallinum* the explants were transferred to fresh medium and process continued till enough shoots were protruded.

The experiment design was Complete Randomized Design (CRD) with six replicates per treatment and each replicate was represented by a culture bottle with four individuals rendering a group of explants (Panse and Sukhatme, 1985).

Results and Discussion

Explants of two different plant species were employed here. In *Syngonium podophyllum* nodal sections were used as explants. It was outlined that all nodal segments and young nodes irrespective of their age if cultured on MS medium supplemented with 5µM BAP resulted satisfactory axillary shoot growth (Geier, 2011). It is evident from the Table: 1 that when benzyladenine (BA) @ 2 mg/l utilized alone 75% established explants were famed as maximum number followed by 54.16% of established explants at the concentration of 3 mg/l while the lowest concentration of it at 1 mg/l resulted minimum response of 33.3%. So solely benzyladenine (BA) at its all three different concentrations not able to yield any noteworthy consequence concerning regeneration of nodal explants especially while not interacted with Naphthalene acetic acid (NAA). But the maximum response regarding regeneration from nodal explants was documented by the treatment interaction between Benzyladenine (BA) @2 mg/l and Naphthalene acetic acid (NAA) @ 0.5 mg/l (87.5%) followed by Benzyladenine (BA) @2 mg/l and Naphthalene acetic acid (NAA) @ 0.1 mg/l (83.3%). All the treatments of Benzyladenine (BA), in general while used in combination with Naphthalene acetic acid (NAA) enhanced the response of explants. Thus it is inferred that in *Syngonium podophyllum* presence of cytokinin is essential along with different levels of auxin in the basic culture media for successful generation. Similar observations also were observed where good regeneration through internodal segments of *Syngonium podophyllum* on MS media containing BAP and kinetin each at 0.5 and 0.2 mg/l concentration (Rajeevan *et al.,* 2002). Engrossingly it was noted that the interaction of Naphthalene acetic acid (NAA) both at the level of 0.1 and 0.5 mg/l with the elevated concentration of Benzyladenine (BA) (3 mg/l) ultimately didn't brought any significant response on explants establishment might be due to the synergistic effect of endogenous and exogenous level of growth regulators (Kunisaki, 2012). However, at this stage apart from any consequential callusing small protuberances emerge from the surface of explants which finally developed into shoots. Least and utmost number of days of 16.8 and 65.6 were found for the color change from pale green to dark green by the interaction of BA @2 mg/l and NAA @ 0.5 mg/l and BA alone respectively (Table 1). For early shoot differentiation minimum 25.2 and 30.4 days after culture initiation was discerned by treatment combination of BA @2 mg/l and NAA @ 0.5 mg/l and BA @2 mg/l and NAA @ 0.1 mg/l respectively. For stimulation of multiple shoot formation the sterile explants were subcultured in the same medium of establishment as multiplication media. At this stage, the treatment combination of BA @2 mg/l and NAA @ 0.5 and 0.1 mg/l both revealed maximum number of shootlets/plant (1.5 at both concentration of NAA) and length of shoots (2.04 & 0.98 at 0.1 and 0.5 mg/l NAA) and leaves (0.98 & 1 at 0.1 and 0.5 mg/l NAA). This concludes the superiority of the treatment combination of BA and NAA in comparison to other treatment in producing healthy shoots within minimum time.

Anthurium crystallinum Lind. a species which derives ornamental value from decorative leaves was attempted in this study employing leaf explants in the same MS media supplemented with BA and NAA. In few experiments leaf explants also were wielded in modified MS and Nitsch medium boosted with BA @ 1mg/l and 2, 4-D @ 0.1mg/l (Malhotra *et al.,* 2011). The experiment with this species of plants couldn't be continued since high rate of microbial contamination, starting from 10-12 days of culturing was observed. Callus formation was also not taken place by any treatments during the period. It was investigated that in case of leaf explants an average contamination rate 10-20% was to be expected while higher rates were experienced in spadix and axillary bud explants (Hessanein, 2015). In *Anthurium*

TABLE 1. Effect of different levels & combination of BA and NAA in MS media on regeneration and multiplication from nodal segments of *Syngonium podophyllum*.

Sl.No.	MS Basal Medium (mg/l)		Explants responded for establishment (Avg. of 24 explants)	Avg. no. of days to complete greening	No. of days for initiation of regeneration	Explants produced shoots (Avg. of 24 explants)	Avg. no. of shootlets /plant	Avg. shoot length (cm)	Avg. leaves length (cm.)
	BA	NAA							
1.	1.0	No Auxin	33.30 (35.24)*	65.6	74.2	16.66 (24.04)*	1.0	0.84	0.42
2.	1.0	0.1	37.30 (37.58)	64.0	72.0	33.2 (35.24)	1.0	0.92	0.46
3.	1.0	0.5	54.16 (47.35)	63.6	70.4	37.3 (37.64)	1.0	0.98	0.48
4.	2.0	No Auxin	75.00 (60.00)	35.6	55.0	79.16 (62.80)	1.0	1.88	0.96
5.	2.0	0.1	83.30 (65.88)	18.6	30.4	83.3 (65.88)	1.5	1.9	0.98
6.	2.0	0.5	87.5 (69.30)	16.8	25.2	87.5 (6.30)	1.5	2.04	1.00
7.	3.0	No Auxin	54.16 (47.35)	60.2	68.2	45.8 (42.59)	1.1	0.98	0.42
8.	3.0	0.1	66.60 (54.70)	40.8	48.0	54.8 (47.35)	1.2	1.02	0.64
9.	3.0	0.5	79.16 (62.80)	30.4	35.2	58.33 (49.78)	1.0	1.08	0.90
	CD (0.01)		**0.0771**			**0.0805**			

*Parenthesis indicate angular transformation value *scherzerianum* spadix explants, a rate up to 75% contaminated cultures also reported by them. To inhibit such contaminations in *Aroids* two antibiotic mixtures of imipenem/ampicillin and imipenem/penicillin at concentrations of 5mg/l each could be applied in tissue culture (Kneifel and Leonhardt, 2014). Retarded rate of contamination was perceived as a resultant effect of use of sterilized explants but any callus development was not detected even after 90 days (Table 2). Such detainment in regeneration also was observed by many researchers. But few scientists contemplated regenerative calli from leaf explants of *Anthurium andreanum* on media containing 2, 4-D and BA after 2-3 months from the day of explants culture (Eapen and Rao, 2013). In the same species callus formation in 1.5-2 months after culturing from leaf explants using media supplemented with 2mg/l kinetin was also found (Kuchule and Sugii, 2012).

Conclusion

For constructing a fruitful method of regeneration through micropropagation, these two ornamental foliage plants viz. *Syngonium podophyllum* and *Anthurium crystallinum* have attracted the attention of the users for the elegant beauty of their foliages which unresistingly lend themselves to use in indoors as potted plants were utilized. As we know, conventional propagation does not yield mass quantity and disease free of plants so micropropagation could be employed for getting large number of plants within shorter period (Aryan and Rani, 2016). Few scientists attempted for *in vitro* multiplication of *Syngonium podophyllum* var. 'White butterfly', a tetraploid variety with large white leaves bearing green margins by using axillary and apical buds from leaf nodes. Induction and multiplication were noted while explants were cultured in MS medium with BA and IAA (Michel, 2010). Here also, treatment combination of BA and NAA exhibited noteworthy output regarding regeneration and multiplication of *Syngonium*'s explants. Micropropagation studies on *Anthurium* have been also found to a large extent. The most pioneer work utilizing different explants formed shoots after subculturing and entire plantlets were obtained after rooting of the shoots accomplished by few researchers (Pierik *et al.,* 2014). Since then various workers noted their success by employing leaf explants (Leffring and Hoogstrate, 2010); (Montel *et al.,* 2009) but in this

TABLE 2. Effect of different levels & combination of BA and NAA in MS media on regeneration from leaf explants of *Anthurium crystallinum* (after treatment with antibiotic).

Sl. No.	MS Basal Medium (mg/l) BA	NAA	No. of pieces inoculated	No. of pieces survived at 90 days	Observation at 90 days of culture
1.	1.0	No Auxin	24	41.66 (40.16)*	Greenish
2.	1.0	0.1	24	37.50 (37.76)	Pale Yellow
3.	1.0	0.5	24	25.00 (30.00)	Lemon Yellow
4.	2.0	No Auxin	24	45.80 (42.59)	Pale Yellow
5.	2.0	0.1	24	20.8 (27.13)	Pale Yellow
6.	2.0	0.5	24	50.00 (45.00)	Greenish Lemon Yellow
7.	3.0	No Auxin	24	33.30 (35.24)	Lemon Yellow
8.	3.0	0.1	24	25.00 (30.00)	Greenish
9.	3.0	0.5	24	37.50 (37.76)	Pale Yellow
	CD (0.01)			**0.114**	

*Parenthesis indicate angular transformation value investigation due to high spoliation any passable result couldn't be procured although this infection was controlled to a good extent after using ampicillin 500mg/ 100mlwater at surface sterilization stage. Comprehensively owing to the superior consequences of micropropagation techniques and growth hormones, successful regeneration of shoots of many ornamental foliage plants can be achieved.

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Literature Cited

Aryan, A. and Rani, P. 2016. Augmentation of ornamental plants using micropropa-gation. Intl. J. of Res. In Biosci., 5, 25-31.

Bhattacharjee SK. 2007. Post harvest management of cut flowers, cut foliages and post production management of potted plants. J. Orn. Hort., 2, 32-39.

Dhananjaya, M.V. and Sulladmath, V.V. 2008. Callus mediated regeneration from petiole explants of *Anthurium andreanum* cv. 'Singapore Hybrid'. J. Orn. Hort., 6, 217-221.

Eapen, S. and Rao, P.S. 2013. Regeneration of plant from callus cultures of *Anthurium patulum*. Curnt. Sci., 54, 284-286.

Geier, T. 2011. Micropropagation of *Anthurium scherzerianum* propagation schemes and plant conformity. Acta Hort., 212, 439-443.

Hessanein, A.M. 2015. A study on factors affecting propagation of shade plant- *Syngonium podophyllum*. J Apl. Hort., 6, 30-34.

Kneifel, W. and Leonhardt, W. 2014. Testing of different antibiotics against gram positive and gram negative bacteria isolated from plant tissue culture. Plnt cell tissue and organ cul., 29, 139-144.

Kozak, M. and Debski, M. 2009. Influence of some cytokinin on shoot development of *Syngonium podophyllum* var. 'White butterfly' *in vitro*. Horticultura., 19, 75-77.

Kuchnle, A.R. and Sugii, N. 2012. Callus induction and plantlet regeneration in tissue cultures of Hawaiian *Anthurium*. Hort Sci., 26, 919-921.

Kunisaki, J.T. 2012. *In vitro* propagation of *Anthurium andreanum* Lind. Hort Sci., 15, 508-509.

Leffring, L. and Hoogstrate, J.C. 2010. Huidige stand Van Zaken Weefsclkweekonderzock *Anthurium andreanum*. Vakblad Bloemisterij., 32,17.

Mahanta, S. and Paswan, L. 2001. *In vitro* propagation of *Anthurium* from axillary buds. J Orn. Hort., 4, 17-21.

Malhotra, S., Puchooa, D. and Goofoolye, K. 2011. Callus induction and plantlet regeneration in three varieties of *Anthurium andreanum*. Agri. et Suc. De I Ile., 77, 25-32.

Michel, H. 2010. *In vitro* propagation of *Syngonium podophyllum* var. 'White butterfly'. Gartenbau., 35, 187-188.

Montes, S., Morales, C. and Bell, E. 2009. Plant regeneration of *Anthurium andreanum* Lind. through *in vitro* culture. Cultivos Tropicales., 25, 5-7.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers. ICAR, New Delhi, pp. 200-45.

Pierik, V., Leeuwen, P. and Righter, G.C.M. 2014. Regeneratiopn of leaf explants of *Anthurium andreanum* Lind. *in vitro* Neth. J Agri. Sel., 27, 221-226.

Rajeeven, P.K., Sheeja, K., Rangan, V.V., Murali, T.P., Mishra, R.L. and Sanyat, M. 2002.

Direct organogenesis in *Syngonium podophyllum*. Proc. of the national symposium on Indian floriculture. 25, 353-354.

Ramphal, H. 1993. Scope of cut flower exports from India. Agri Marketing., 36, 25-30.

Sindhu, M., Eapen, S. and Rajeevan, P.K. 2005. Evaluation of tropical plant species for *foliage characters. J Orn. Hort., 8, 1-7.*

Swarup, V. 1993. Floriculture industry in India. J Orn. Hort., 1, 18-26.

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Performance of Chickpea (*Cicerarietinum* L.) under Different Hydro Thermal Regimes on Yield and Yield Attributing Characters

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Abstract

A field experiment was conducted for two consecutive years 2014-15 and 2015-16 at Anand Agricultural University, Anand, Gujarat, India with three dates of sowing and four irrigation levels. The sowing dates D_1-15th October, D_2- 30th October and D_3- 15th November with irrigation levels treatments namely I_1- Irrigation at critical growth stages, I_2- 0.4 IW: CPE, I_3- 0.6 IW: CPE and I_4- 0.8 IW: CPE to evaluate the optimum sowing time and irrigation level for chickpea (*Cicerarietinum* L.) under different hydro-thermal regimes. The differences were higher for D_2 (2179 kg ha^{-1}) than D_3(2079 kg ha^{-1}) and D_1 (1853 kg ha^{-1}) dates of sowing during 2014-15. Whereas, during 2015-16 the differences in seed yield of chickpea sown on D_2 (2075 kg ha^{-1}) being at par with D_3 (1949 kg ha^{-1}) sowing were significantly higher than D_1 (1729 kg ha^{-1}). Among the different irrigation treatments, the differences in the seed yield were significantly higher for I_3(2230 kg ha^{-1}) irrigation treatment than I_1(2064 kg ha^{-1}), I_4 (1992 kg ha^{-1}) and I_2(1861 kg ha^{-1}) respectively, during 2014-15. Whereas, the seed yield of chickpea for irrigation treatment I_3 was significantly higher (2153 kg ha^{-1}) than I_1 (2013 kg ha^{-1}), I_4 (1861 kg ha^{-1}) and I_2 (1728 kg ha^{-1}) during 2015-16.

Key words: Chickpea, Date of sowing, IW:CPE ratio and seed yield.

Introduction

Chickpea is generally known as Bengal gram or Gram and botanically called *Cicerarietinum* Linn. It is the oldest and most important crop, mostly grown under dry land condition with heavy cloddy soil. It has an important place in the diet of Indian people because it gives comparatively more protein than any other food grains. Gram contains 21.5 % protein, 61.5 % carbohydrates and 4.5 % fat (Ahlawat and Omprakash, 1996).

In India, pulses are cultivated on marginal lands under rainfed conditions. Only 15% of the area under pulses has assured irrigation. India having the largest share of about 25% production, about 33% acreage and about 27% consuming of total pulses of the world, the acreage ranged from 20.35 (2000-01) to 23.99 million ha (2012-13) and production varied from 11.08 (2000-01) to 18.45 million tonnes (2012-13), respectively. Estimated area, production and productivity during 2013-14 is 9.92 million hectares, 9.52 million tonnes and 960 kg ha^{-1}, respectively (Annon, 2015).

Materials and Methods

Experimental details

The experiment was laid out at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during *rabi* seasons of 2014-15 and 2015-16 in split plot design with date of sowing as main plot (D_1- 15th October, D_2- 30th October and D_3- 15th November) and irrigation as sub plot treatment (I_1- Irrigation at critical growth stages:Branching, flowering and pod development, I_2- 0.4 IW: CPE, I_3- 0.6 IW: CPE and I_4- 0.8 IW: CPE). The soil type of the experimental site was sandy loam a true representative soil of the region. Recommended agronomic practices were followed to raise the crop. The observation on the meteorological parameters for the period of investigation recorded at the meteorological observatory of the Anand Agricultural University, Anand. The cumulative pan evaporation values were calculated from daily pan evaporation measured with the help of USWB class 'A' open pan evaporimeter installed at meteorological observatory, which was in the proximity of the experimental plot.

Yield attributes and other biometric observations were taken from 10 selected plants from each plot. Seed and biological yields were recorded from individual plots and expressed in kg ha^{-1}.

Results and Discussion

The results of seed yields and various yield attributing characters are presented and discussed in pursuance of the objectives set forth for the study.

Yield and yield components

The results revealed that higher plant height (32.74 cm and 30.70 cm during 1st and 2nd year, respectively),number of pods $plant^{-1}$ (29.53 and 30.58 during 1st and 2nd year, respectively), number of branches $plant^{-1}$ (3.96 and 4.26 during 1st and 2nd year, respectively), leaf area index (3.50 and 3.54 during 1st and 2nd year, respectively), seed weight $plant^{-1}$(11.14 g and 13.50 g during 1st and 2nd year, respectively) and test weight (19.56 g and 18.70 g during 1st and 2nd year, respectively). Similarly, significantly higher seed yield (2179 kg ha^{-1} and 2075 kg ha^{-1} during 1st and 2nd year, respectively) and biomass (5855 kg ha-1 and 5729 kg ha-1 during 1st and 2nd year, respectively) were observed with 2nd date of sowing. (Table 1 and 2). This result was corroborated with the findings of Sahu *et al.* (2007), Trivedi and Vyas (2000), Mansur *et al.* (2010) and Agrawal *et al.* (2010)

Application of irrigation at 0.6 IW: CPE ratio resulted in higher number of pods $plant^{-1}$ (29.40 and 29.64 during 1st and 2nd year, respectively), seed weight $plant^{-1}$ (11.07 g and 13.22 g during 1st and 2nd year, respectively), test weight (19.48 g and 19.41 g during 1st and 2nd year, respectively), seed yield (2230 kg ha^{-1} and 2153 kg ha^{-1} during 1st and 2nd year, respectively), harvest index (39.49 and 38.58 during 1st and 2nd year, respectively). However higher plant height (32.65 cm and 31.75 cm during 1st and 2nd year, respectively), number of branches $plant^{-1}$ (4.28 and 4.59 during 1st and 2nd year, respectively), leaf area index (3.72 and 3.65 during 1st and 2nd year, respectively) and biomass yield (5984 kg ha^{-1} and 5856 kg ha^{-1} during 1st and 2nd year, respectively) (Table 1 and 2). The results were in good conformity with the findings of Ahlawat *et al.* (2005), Mustafa *et al.* (2008), Mansur *et al.* (2010) and Ray *et al.* (2011).

Quality parameter

Higher protein content (21.09 % and 21.32 % during 1st and 2nd year, respectively) was found under 3rd date of sowing while under irrigation treatments higher protein content (21.95 % and 22.20 % during 1st and 2nd year, respectively) was found under I_3 irrigation treatment.Similar type of result were observed by Mansur *et al.* (2010).

Conclusion

The overall performance with respect to the seed yield of chickpea for D_2 date of sowing and I_3 (0.6 IW: CPE) irrigation treatment were significantly higher during both the year of experiment as compared to rest of the treatment combinations. This sowing window provide optimum weather condition during crop growing season. The differences accrued mainly due to higher dry matter produced, increased number of pods $plant^{-1}$, seed weight $plant^{-1}$ and test weight for D_2 date of sowing under I_4 irrigation level. The higher seed yield can be in part, attributed to longer duration for anthesis and pod development.

Literature Cited

Agrawal, K. K., Bhadauria, U. P. S., Jha, A. and Jain, S. (2010). Crop weather relationship studies on chickpea for improving crop adaptation to climate change. *Int. J. Trop. Agri.*,**28** (1-2): 239-242.

Ahlawat, I. P. S., Gangaiah, B. and Singh, O. (2005). Irrigation requirement in gram

TABLE 1. Plant height, number of pods plant^{-1}, number of branches plant^{-1}, leaf area index and seed weight plant^{-1} influenced by date of sowing and irrigation levels

Treatments	Plant height (cm)		Number of pods plant^{-1}		Number of branches plant^{-1}		Leaf area index		Seed weight plant^{-1} (g)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Mean for date of sowing										
D_1	30.50	29.15	25.63	26.16	3.51	3.15	3.45	3.34	9.71	10.66
D_2	32.74	30.70	29.53	30.58	3.96	4.26	3.50	3.54	11.14	13.50
D_3	28.88	27.97	26.01	27.27	3.71	3.93	3.46	3.49	9.86	12.02
S.Em. ±	0.71	0.64	0.88	0.99	0.09	0.06	0.04	0.17	0.23	0.29
C.D. at 5%	2.48	NS	3.05	3.44	0.32	0.23	0.14	NS	0.81	1.01
C.V. %	9.35	8.84	13.04	14.20	10.00	7.14	4.57	16.87	9.18	9.71
Mean for irrigation levels										
I_1	31.93	30.02	27.80	28.77	3.65	3.41	3.47	3.40	10.53	12.93
I_2	28.15	26.57	24.64	25.91	3.00	2.94	3.27	3.32	9.30	10.26
I_3	30.09	28.76	29.40	29.64	3.98	4.18	3.60	3.54	11.07	13.22
I_4	32.65	31.75	26.38	27.70	4.28	4.59	3.72	3.65	10.04	11.83
S.Em. ±	0.92	0.51	0.75	0.80	0.12	0.14	0.05	0.09	0.29	0.37
C.D. at 5%	2.95	1.63	2.40	2.56	0.39	0.44	0.17	0.30	0.93	1.18
C.V. %	10.43	9.06	9.62	9.93	8.34	7.85	5.29	7.20	9.91	10.62

TABLE 2. Test weight, seed yield, biomass yield, harvest index and protein content influenced by date of sowing and irrigation levels.

Treatments	Test weight (g)		Seed yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		Harvest index (%)		Protein content (%)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Mean for date of sowing										
D_1	17.65	16.31	1853	1792	5194	5161	35.79	34.79	19.95	19.46
D_2	19.56	18.70	2179	2075	5855	5729	37.50	36.42	20.13	20.79
D_3	18.11	17.92	2079	1949	5712	5558	36.78	35.31	21.09	21.32
S.Em. ±	0.46	0.89	46.48	41.62	157.45	113.60	1.18	1.00	0.34	0.34
C.D. at 5%	NS	NS	160.86	144.04	544.86	393.14	NS	NS	NS	1.20
C.V. %	10.08	12.39	9.12	8.58	9.76	8.28	12.86	11.26	6.82	6.76
Mean for irrigation levels										
I_1	17.85	17.06	2064	2013	5527	5358	37.34	37.56	21.07	20.57
I_2	17.16	16.16	1861	1728	5190	5136	35.86	33.64	18.82	18.83
I_3	19.48	19.41	2230	2153	5646	5579	39.49	38.58	21.95	22.20
I_4	19.27	17.94	1992	1861	5984	5856	33.28	31.77	19.72	20.50
S.Em. ±	0.65	3.01	52.21	47.66	163.09	118.73	1.75	1.42	0.52	0.48
C.D. at 5%	NS	NS	167.04	152.47	521.79	379.82	NS	NS	1.66	1.56
C.V. %	6.28	7.50	10.88	11.51	10.11	9.50	8.55	10.85	8.83	8.25

(*Cicerarietinum*) and Indian mustard (*Brassica juncea*) intercropping system. *Indian J. Agri. Sci.,* **75** (1): 23- 26.

Annon. (2015). http://eands.dacnet.nic.in

Mansur, C. P., Palled, Y. B., Halikatti, S. I., Chetti, M. B. and Salimath, P. M. (2010). Pattern of leaf area, canopy width and dry matter production in chickpea as influenced by dates of sowing and irrigation levels. *Karnataka J. Agri. Sci.***23** (4): 461-463.

Mustafa, M. N., Sagar, K. G., Chandrika, V. and Reddy, P. M. (2008). Growth and yield of chickpea as influenced by irrigation and nutrient management. *Leg. Res.,* **31** (3): 221-223.

Ray, M., Nanda, M. K. and Khan, D. K. (2011). Effect of date of sowing and irrigation on seed yield, yield attributes and water use of chickpea (*Cicerarietinum* L.) at lower gangetic planes of West Bengal. *J. Crop and Weed*, **7** (2): 30-32.

Sahu, D. D., Chopada, M. C. and Patoliya, B. M. (2007). Determination of sowing time for chickpea varieties in south Saurashtra, India. *J. Agromet.,* **9** (1): 68-73.

Trivedi, K. K. and Vyas, M. D. (2000). Response of Kabuli chickpea cultivars under different dates of sowing and row spacing. *Crop Res. Hissar*, **20** (1): 52-55.

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Optimization of Biopolymer (Chitosan) Based Finish on Cotton for Imparting Crease Resistance

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Abstract

Chitosan, a natural polysaccharide, is a derivative of chitin, which is commonly found in shells and exoskeletons of some crustacean and is the second most abundant bio-polymer with unique structural and physiological characteristics. They have a unique combination of properties such as biocompatibility, biodegradability and antibacterial activity which makes it an ideal polymer for industrial applications in the field of textiles and biomedical. It also solves the problem of waste deposition, replaces the harsh chemicals used for providing different types of finish on different fabrics and helps in controlling the pollution, which is the biggest concern for the textile industry now a days. In the present study the chitosan was used to impart crease resistant finish to the cotton fabric with the help of citric acid which is used as crosslinking agent. The finish was applied on the pure cotton fabric by using pad-dry-cure method. Before application of finish different chemicals present in the finish were standardized. It was found that the crease recovery angle of the fabric increased with the optimized concentrations of chemicals. The optimum concentration of the chemicals were 4% chitosan,10% citric acid, 6% catalyst, 6% silicon softener and 1:20 M: L ratio.

Keywords: Crease resistant finish, Chitosan, Citric acid.

Introduction

Cotton popularly known as "White Gold" is grown mainly for fiber. India has been a traditional home of cotton and cotton textiles. In India cotton is used extensively for apparel purpose. It has many qualities which make it suitable for apparel purpose such as absorbency, strength, easily spinnable, washability, good conductor of heat which leads to comfort in wear during hot weather. It can bear high dry heat and high ironing temperature. But there are certain drawbacks associated with cotton fabric such as low elasticity and low resiliency which creates wrinkles. Cellulose materials are highly prone to creasing. Creasing occurs when fibers are stressed. This crease resistance is important property of the fabric, which causes the fabric to recover from folding deformations that normally occur during its use. Alternatively, the cross-links may be strained without breaking and show a recovery on deloading. To solve the problem of wrinkle, crease resistant finish, usually applied to fabrics made from cotton or other cellulosic fibres which improves the crease recovery and smooth-drying properties of a fabric. The recovery depends on time, varying for different fabrics from an instantaneous recovery to slow disappearance of the creases. Chitosan shows anti-crease property if it is applied on the cotton fabric as a finish. This study will be an attempt to solve the problems which are associated with *cotton* fibre such as wrinkle and bacterial problem. The use of natural fibres is encouraged because natural fibres are also good source for textiles as they are renewable resources.

Materials and Methods

For the application of crease resistant finish the pure grey cotton fabric was purchased. It has fabric count 50 ends and 49 picks, 103.6 g/m^2 weight per unit area with 0.31 mm thickness. Then it was given scouring pre-treatment to remove the vegetative impurities from the grey cotton fabric. The scouring the grey cotton fabric was done by sodium hydroxide for two hours. After scouring the fabric count of the fabric increased while the weight per unit area and thickness of the fabric decreased. fabric count became 52 ends × 51 picks ,weight per unit area changed into 100.8 g/m^2 having 0.29 mm thickness. Chitosan with 82% degree of deacetylation was purchased from Indian sea Food Company for application of finish. Citric acid, catalyst and silicon softener were also used along with chitosan. The crease resistant finish was applied on scoured cotton fabric by using pad dry cure method. After standardizing different concentrations of chemicals, Crease resistant finish was optimized at different concentrations of chemicals: chitosan (1%, 2%, 3%, 4% and 5%), citric acid (4%, 6%, 8%, 10% and 12%), silicon softener (4%, 6%, 8%, 10% and 12%), catalyst (2%, 4%, 6%, 8% and10%) and M : L ratio (1:10, 1:15, 1:20, 1:25 and 1:25). For the determination of optimum concentrations of chemicals, basic properties viz. crease recovery angle, tensile strength, elongation were measured. After optimization of concentrations of chemicals, the finish was finally applied on the cotton fabric. Cotton fabric was first impregnated in a solution containing the finish. To obtain better crease recovery properties with minimum tensile strength loss, experiments were conducted to optimize various concentrations of different chemicals used to impart the crease resistant finish viz. concentrations of chitosan, citric acid, catalyst, silicon softener, M: L ratio. Three basic properties were used to optimize crease resistant finish.

Results and Discussion

The concentration of chitosan which will be used to apply the finish was optimized with reference to its concentrations.

Determination of optimum concentration of chitosan

With the perusal of results obtained in the Table 1 five different concentrations of chitosan 1%, 2%, 3%, 4% and 5% were taken for the determination of optimized concentration of chitosan. When one percent concentration of chitosan is applied on the scoured fabric (control fabric),then there was 101.0 degree increase in the crease recovery angle, tensile strength with loss was 13.86 kg and 17.30 % elongation of the treated fabric. As the concentration of the chitosan increased from 1% to 5 %, there was increase in the crease recovery angle (19.04 %), loss in tensile strength (11.63 %) and elongation (14.95%) of the treated fabric as compared to the scoured fabric (control) which have 84.6 degree crease recovery angle, 14.70 kg tensile strength and 21.40 % elongation. It is clear from the table that as the concentration of chitosan is increased for the application of finish from 1 % to 5 %. Then, there was increase in the crease recovery angle from 101.0 degree to 104.5 degree and tensile strength decreased from 13.86 kg to 12.99 kg with decrease in elongation from 19.15 % to 14.95 %. Therefore 4% conc. of chitosan was chosen as optimum conc. for application of finish, at which there was increase in crease recovery angle with less tensile strength loss.

Results showed that with the increased concentration of chitosan the crease recovery angle of the fabric increased whereas the tensile strength of the fabric decreased. Tensile strength loss may be because of higher concentration of chitosan which directly affect the fibre structure and chitosan crosslinking of the cellulose reduces the mobility of the macromolecules with greater stress, which could not be uniformly distributed among the polymer chain, was accumulated in the fabric structure, leading to its disruption. Thus the crosslinking of cellulose molecules reduced the strength of chitosan treated fabric.

Determination of optimum concentration of citric acid

The concentration of citric acid as crosslinking agents was optimized with varied concentrations. Citric acid is a common ingredient of crease resistant finish, used as crosslinking agent which improves the crease recovery angle of the fabric. The different percentages of citric acid i.e. 4%, 6%, 8%, 10% and 12% were used. The crease recovery angle and tensile strength of the fabric was observed. The data presented in Table 2 depict when concentration of citric acid was taken as 4 % then crease recovery angle was observed as 102.5 degree with 13.98 kg tensile strength and 17.21 % elongation. But as the concentration of citric acid increased from 4 % to 12 % then crease recovery angle was observed as 106.1 degree with 12.98 kg tensile strength and 18.10 % elongation. It is evident from the results that with the increase in the percent of citric acid, the increase in crease recovery angle was from 17.46 % to 20.26 %, tensile strength loss was from 4.89 % to 11.70 % with elongation loss 19.57 % to 14.20 %.

The data in table reckons that crease recovery angle was assessed maximum under the 12 % use of citric acid with maximum strength loss and elongation (18.10%).The crease recovery angle with the use of 10 % citric acid was found optimum with less tensile strength loss as compared to the use of 12 % conc. of citric acid. Therefore 10 % of citric acid was taken as an optimum concentration at which increase in the crease recovery was 105.8 degree with loss in tensile strength (13.10 kg) along with 17.98 % elongation. This may be due to more carboxylic (-COOH) groups which are capable of triggering more esterification: therefore, more crosslinking are formed with the cotton fibres and chitosan. Due the crosslinking crease recovery angle of the fabric increased but it has negative effect on tensile strength. With the increase in crosslinking the cotton fibres become stiff and as a result loss in tensile strength occurred.

Determination of optimum concentration of catalyst (Di-sodium hypophosphite)

For applying the finish different concentrations of catalyst were taken to optimize the concentration of catalyst. It is evident from the Table 3 as the concentration of the catalyst was increased; there was noticeable change in the crease recovery angle and tensile strength. At two percent conc. of the catalyst, the crease recovery angle was 101.2 degree, tensile strength 13.52 kg and 17.84 % elongation.

As the concentration of catalyst increased from 2 % to 10 %, there was % increase in the crease recovery angle from 16.40 % to 19.61 %, percent loss in tensile strength was 8.03 % to 19.31 % and percent loss in elongation was from 16.63 % to 11.16%. When it was compared with scoured fabric for which the crease recovery angle was 84.6 degree and tensile strength as 14.70 kg along with 21.40 % elongation. Therefore 6 % conc. of catalyst has been selected for application of finish as there was increase in crease recovery angle (104.7 degree) with 12.86 kg tensile strength and 18.64 % elongation. The results unveiled that the crease recovery angle increased with increase in concentration of catalyst where as the tensile strength decreased. This may be due to the fact Co-valent bonds are stronger bonds than the hydrogen bonds and more energy is required to break those bonds. So they do not break easily when they come in contact with water during laundering, sweating and fabric deformation (bending). Thus due to the crosslinking tensile strength decreases, Because of keeping the cellulose molecules in their respective positions, the movements of cellulose molecules resists and the fabric becomes stiff. Due to the stiffness tensile strength of the fabric decreases.

Determination of optimum concentration of silicon softener (sarapeach AM)

Different concentrations of silicon softener i.e. 2%, 4%, 6%, 8% and 10% were tried with the optimized concentrations of chemicals with different conditions.Table 4 unveils that when 2 % conc. of silicon softener was applied to the scoured fabric (control), the crease recovery angle was obtained 101.65 degree, tensile strength 12.99 kg and elongation 19.00 %.

With progressive increase in conc. of silicon softener from 2 % to 10 %, the crease recovery angle was increased from 101.65 degree to 105.9 degree, tensile strength decreased from 12.99 kg to 11.89 kg and elongation also decreased from 19 % to 20.04 %. When the results were compared with control scoured fabric, there was progressive increase in the crease recovery angle from 16.77 % to 20.11 % and percent loss in tensile strength was 11.63 % to 19.11 % along with elongation percent loss 11.21 % to 6.35 %. There

TABLE 1. Determination of optimum concentration of chitosan

Fabric Properties / Conc. of Chitosan		Crease Recovery Angle (Degree) Warp	Weft	Mean	% change increase recovery angle	Tensile Strength (Kg)	% change in tensile Strength	Elongation (%)	%change in elongation
Treated Fabric	1%	101.8	100.2	101.0	+16.23	13.86	-5.71	17.30	-19.15
	2%	104.4	102.2	103.3	+18.10	13.72	-6.67	17.46	-18.41
	3%	104.6	103.2	103.9	+18.58	13.68	-6.94	17.72	-17.20
	4%	**105.4**	**103.4**	**104.4**	**+18.96**	**13.60**	**-7.48**	**17.80**	**-16.82**
	5%	105.5	103.5	104.5	+19.04	12.99	-11.63	18.20	-14.95
Controlled Fabric		**85.6**	**83.6**	**84.6**	**-**	**14.70**	**-**	**21.40**	**-**

+ = Increase, - = Decrease

TABLE 2. Determination of optimum concentration of citric acid

Fabric Properties / Conc. of Citric acid		Crease Recovery Angle (Degree) Warp	Weft	Mean	% change increase recovery angle	Tensile Strength (Kg)	% change in tensile Strength	Elongation (%)	%change in elongation
Treated Fabric	4%	102.8	102.1	102.5	+17.46	13.98	-4.89	17.21	-19.57
	6%	105.2	103.4	104.3	+18.89	13.82	-5.99	17.46	-18.41
	8%	106.4	104.4	105.4	+19.73	13.72	-6.67	17.86	-16.54
	10%	**106.7**	**104.9**	**105.8**	**+20.03**	**13.10**	**-10.88**	**17.98**	**-15.98**
	12%	106.8	105.4	106.1	+20.26	12.98	-11.70	18.10	-14.20
Controlled Fabric		**85.6**	**83.6**	**84.6**	**-**	**14.70**	**-**	**21.40**	**-**

+ = Increase, - = Decrease

was negligible difference between crease recovery angle and elongation at 6% and 8% conc. of silicon softener but there was difference in the tensile strength of the fabric so the 6% conc. of silicon softener was selected as Aoptimum conc. for application of finish with less tensile strength loss. This may be due to the fact that the silicon softener binds with the cellulose molecules through crosslinking reaction and the co-valent bonds are formed among the cellulose molecules with silicon softener. These bonds resist the displacement of the cellulose molecules resulted to resist the crease formation means increase in crease recovery angle. Another reason may be that with the increase in crosslinking, crease recovery angle also increased with decrease in tensile strength, there is linear relationship exist between the crosslinking and tensile strength.

Determination of optimum concentration of material to liquor ratio

Material to liquor ratio play a vital role in the application of finish. For application of finish, the bath was prepared with the different material to liquor Ratios i.e. 1:10, 1:15, 1:20, 1:25 and 1:30 with the optimized variables. The fabric was dipped into the bath and passed through padding mangle rollers, dried and cured at the optimized limit.

TABLE 3. Determination of optimum concentration of catalyst (di-sodium hypophosphite)

	Fabric Properties / Conc. of Catalyst	Crease Recovery Angle (Degree) Warp	Weft	Mean	% change increase recovery angle	Tensile Strength (Kg)	% change in tensile Strength	Elongation (%)	%change in elongation
Treated Fabric	2%	102.4	100	101.2	+16.40	13.52	-8.03	17.84	-16.63
	4%	104.6	102.8	103.7	+18.41	13.10	-10.88	18.30	-14.49
	6%	**105.8**	**103.6**	**104.7**	**+19.20**	**12.86**	**-12.51**	**18.64**	**-12.89**
	8%	105.9	103.9	104.9	+19.39	12.20	-14.70	18.96	-11.40
	10%	106.1	104.4	105.3	+19.61	11.86	-19.31	19.01	-11.16
Controlled Fabric		**85.6**	**83.6**	**84.6**	**-**	**14.70**	**-**	**21.40**	**-**

+ = Increase, - = Decrease

TABLE 4. Determination of optimum concentration of silicon softener (Sarapeach AM)

	Fabric Properties / Conc. of Silicon Softener	Crease Recovery Angle (Degree) Warp	Weft	Mean	% change increase recovery angle	Tensile Strength (Kg)	% change in tensile Strength	Elongation (%)	% change in elongation
Treated Fabric	2%	102.1	101.2	101.65	+16.77	12.99	-11.63	19.00	-11.21
	4%	105.2	104	104.6	+19.12	12.76	-13.19	19.18	-10.37
	6%	**105.8**	**104.8**	**105.3**	**+19.65**	**12.36**	**-15.92**	**19.62**	**-8.31**
	8%	106.0	105.4	105.7	+19.96	12.12	-17.55	19.82	-7.38
	10%	106.1	105.7	105.9	+20.11	11.89	-19.11	20.04	-6.35
Controlled Fabric		**85.6**	**83.6**	**84.6**	**-**	**14.70**	**-**	**21.40**	**-**

+ = Increase, - = Decrease

Data in Table 5 indicate that when 1:10 material to liquor ratio was used for application of chitosan and citric acid based crease resistant finish on the scoured cotton fabric (control fabric), the crease recovery angle was obtained 104.7 degree, tensile strength 12.84 kg and 18.43 % elongation. As the material to liquor ratio was increased from 1:10 to 1:20, there was increase in the crease recovery angle from 104.7 degree to 105.45 degree and loss in tensile strength was from 12.84 kg to 12.22 kg along with loss in elongation from 18.43 % to 19.12 %. But further increase in 1:25 to 1:30 material to liquor ratio, there was decrease in the crease recovery angle 104.1 degree and loss of tensile strength 12.98 kg also reduced along with elongation. But after increase in 1:20 material to liquor ratio there was not further increase in crease recovery angle with progressive material to liquor ratio (1:25 and 1:30). There was slight decrease in the crease recovery angle. It was observed that after certain limit further increase in material to liquor ratio, the crease recovery angle of fabric did not increases but it decreased slightly. So the 1:20 M: L ratio was taken as optimum m: L ratio for application of finish with maximum crease recovery angle and minimum tensile

TABLE 5. Determination of optimum material to liquor (M: L) ratio

	Fabric Properties / M : L Ratio	Crease Recovery Angle (Degree) Warp	Weft	Mean	% change increase recovery angle	Tensile Strength (Kg)	% change in tensile Strength	Elongation (%)	%change in elongation
Treated Fabric	1:10	105.0	104.5	104.7	+19.19	12.84	-12.65	18.43	-15.79
	1:15	105.2	104.6	104.9	+19.35	12.62	-14.14	18.98	-11.30
	1:20	**106.0**	**104.9**	**105.45**	**+19.77**	**12.22**	**-16.87**	**19.12**	**-10.65**
	1:25	105.0	104.0	104.5	+19.04	12.50	-14.96	18.00	-13.08
	1:30	105.0	103.2	104.1	+18.73	12.98	-11.70	17.83	-13.87
Controlled Fabric		**85.6**	**83.6**	**84.6**	**-**	**14.70**	**-**	**21.40**	**-**

+ = Increase, - = Decrease

strength loss. This may be due the material to liquor ratio, the finish content present in the liquor was in diffuse form as the material to liquor increases the diffusion of the finish content increased in the liquor, when the content of the finish was in more diffused form, it required more time to be absorbed in the scoured fabric. Before padding the fabric is dipped in finish solution for few minutes at that time it cannot absorb whole content of finish. A further increase in the material to liquor ratio resulted in less deposition of chitosan and citric acid within the fabric because it cannot absorb all the contents hence a lower material to liquor ratio gave better results.

Conclusions

It is evident from the results that the crease recovery angle of the fabric increased with the increase in the conc. of different chemicals but it has opposite effect on the tensile strength of the fabric and elongation but the tensile loss is common if we apply any finish. This finish will be helpful for imparting the ecofriendly crease resistant finish to the cotton fabric because chemicals used in for imparting finish are ecofriendly and biodegradable in nature. This finish will also helpful for the workers who work in the textile finishing sector and suffers from the health hazards caused by carcinogenic chemicals used for imparting crease resistant finish such as DMDHEU.

Literature Cited

Can, Y., Akaydin, M.(2009) Effect of Wrinkle Resistant Finish on Cotton Fabric Properties, *Indian Journal of Fibre and Textile Research*, **34:** 183-186

Chattopadhyay, D. P., Sharma, D. N. and De, P. (1998). Studies on Formaldehyde –Free Crease-Resistant Finishing of Cotton Fabric Using Citric Acid and Selective Chemical Additives. *Indian Journal of Fibre and Textile Research,* **24**: 284-289.

Devaraj, T. S. (2011).A Report on Present Scenario of Cotton, pp: 10

Joshi, M. Ali, S. W. and Purwar, R. (2009). Ecofriendly Antimicrobial Finishing Of Textile Using Bioactive Agents Based On Natural Products. *Indian Journal of Fibre and Textile Research*, **34**:295-304.

Singh, G. (2010). Comparative Investigations on the Efficiency of Different Anchoring Chemicals for the Permanent Finishing of Cotton with Chitosan, *Indian Journal of Fibre and Textile Research*, **11** (2).

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Field Screening of Pigeonpea Genotypes Against the Infestation of Lepidopteran Pod Borers

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Abstract

Twenty nine long duration pigeonpea genotypes were screened for their resistance against lepidopteran pod borers during *Kharif* 2014-15 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The pigeonpea was infested with a number of insect pests at various stage of crop growth. Out of which the incidence pattern of three important lepidopteran pod borers, *Helicoverpa armigera, Lampides boeticus* and *Exelastis atomosa* was studied. The first incidence of these pod borers was observed in the 4^{th} standard week and their population persisted up to 12^{th} standard week in all the genotypes. The peak population of these pod borers was observed between 10^{th} to 11^{th} standard weeks in different genotypes. The per cent pod damage due to lepidopteran pod borers significantly varied from 4.33 per cent in genotype IVT-520 to 11.67 per cent in genotype IVT-502. The highest grain damage by pod borers was also seen in IVT-510 (4.90%) while the lowest grain damage was observed in IVT-520 (1.07%). The grain yield of different genotypes also differed significantly and ranged from 479 kg/ha in the genotype IVT-510 to 3314 kg/ha in IVT-520.

Key words: Pigeonpea, Screening, *Helicoverpa armigera*, *Lampides boeticus*, *Exelastis atomosa*

Introduction

Pulses are the most important food crops in India whose role in Indian Agriculture hardly needs any emphasis. They form an integral part of the cropping system of the farmers all over the country because these crops fit well in crop rotation and crop mixtures. They also form an integral part of the vegetarian diet in the Indian Sub-Continent. Pigeonpea, *Cajanus cajan* (L.) Millsp. is the most important pulse crop grown in India after chickpea. India accounts for more than 90 per cent of the world's pigeonpea production and area (Mathukia *et al*., 2016). In India pigeonpea is grown on 3.88 million hectares of area with an annual production of 3.29 million tonnes and yield of 849 kg/ha (Anonymous, 2014). Though, India is largest producer of pigeonpea, its productivity has always been a concern. The low productivity of pigeonpea in the country may be attributed to many reasons, among which damage by insect pests is of paramount importance.

More than 250 species of insects are known to infest pigeonpea crop at its various growth stages but of these only a few cause significant and consistent damage to the crop (Gopali *et al*., 2010) and as per a conservative estimate, losses due to these insect pests may vary from 27 per cent to even 100 per cent (Srilaxmi and Paul, 2010). The key pests of long duration pigeonpea include gram pod borer, *Helicoverpa armigera* (Hübner); tur pod fly, *Melanagromyza obtusa* (Malloch). Others such as tur pod bug, *Clavigralla gibbosa* Spinola; blue butter fly, *Lampides boeticus* (L.); plume moth, *Exelastis atomosa* (Walsingham) and spotted pod borer, *Maruca vitrata* (Geyer) are also potential pests and occasionally cause significant grain yield losses in long duration pigeonpea. The pod borer complex along with pod sucking bugs significantly reduces the pigeonpea crop yield to an extent of 60 to 90 per cent (Sujithra and Chander, 2014).

It has long been recognized that host plant resistance holds a great promise for exploitation in integrated pest management programmes because the use of resistant cultivarss provide crop protection that is biologically, ecologically, economically and socially acceptable. Since pigeonpea growers have to spend much on input like chemical pesticides, therefore also it is considered viable to search the available germplasms for sources of resistance to this insect pest for use in breeding insect resistant cultivars. Thus, keeping these views in mind, the present study was conducted to identify resistant sources so as to evolve long duration cultivars less susceptible to pod fly in pigeonpea.

Materials and Methods

The present investigation was carried out at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif*, 2014–15. Twenty nine long duration pigeonpea genotypes/varieties [IVT-501, IVT-502, IVT-503, IVT-504, IVT-505, IVT-506, IVT-507, IVT-508, IVT-509, IVT-510, IVT-511, IVT-512, IVT-513, IVT-514, IVT-515, IVT-516, IVT-517, IVT-518, IVT-519, IVT-519, IVT-520, IVT-521, AVT-601, AVT-602, AVT-603, AVT-604, AVT-605, AVT-606, AVT-607, AVT-(MAL13*846)] were grown each in plots of 3 rows of 4 m length following row to row and plant to plant spacing of 75 cm and 30 cm respectively. The crop was grown following the normal agronomic practices in "Randomized Block Design (RBD)" with three replications. The crop was sown on 26th July 2014 (30th standard week) and harvested on 7th April 2015 (15th standard week) respectively.

For recording the population of lepidopteran pod borers, five plants were randomly selected from each genotype and each unit plot and the total number of larvae of different species of pod borers present on them was counted at weekly intervals, from 24th January to 20th March, 2015. The number of insect count recorded from all the three replications and for all the genotypes were averaged separately for each genotype on standard week basis. The sampling for pod and seed damage assessment due to lepidopteran pod borers was done at 80% maturity stage of the crop. For pod and grain damage assessment, five plants from the three central rows in each plot were selected randomly and all the pods from five plants were pooled together and finally 100 pods were picked up and observations were recorded. Later, the percent pod and grain damage was also worked out. The grain yield was also recorded for each plot after excluding the border rows on the two sides of the plot and then extrapolated into kg/ha.

Statistical Analysis

All the data recorded were subjected to statistical analysis as per the Randomized Block Design procedure. The insect population data were transformed with square root transformation $\sqrt{x+0.5}$ method and damage assessment data were transformed by arc sin (q = sin-1x) transformation method.

Results and Discussion

Twenty nine pigeonpea genotypes/varieties were screened under unprotected conditions for studying the damage assessment in relation to per cent pod and grain damage due to lepidopteran pod borers during 2014-15. The results obtained from the investigation as well as relevant discussion have been summarized under the following heads:

Incidence pattern of lepidopteran pod borers on different pigeonpea genotypes

Gram pod borer (*Helicoverpa armigera*)

During 2014-15, the first incidence of pod borer, *H. armigera* larvae was observed in 4th standard week in all genotypes except IVT-520, IVT-504, IVT-505, IVT-509, IVT-503, AVT-603, AVT-601 and AVT-605. In genotypes IVT-520, IVT-504, IVT-509, the population was observed in 6th standard week. The peak population was recorded between 10th to 11th standard weeks in all genotypes (Table 1). The mean population of pod borer also differed significantly among the genotypes and ranged from 0.40 larvae/ plant in IVT-520 to 0.93 larvae/ plant in IVT-510. The results are in agreement with Kumar and Nath (2003)

TABLE 1. Population of gram pod borer, *H. armigera* on pigeonpea genotypes during *Kharif* 2014-15

Genotypes	Number of maggots per 10 pods*									
	4^{th} S.W. 24 Jan.	5^{th} S.W. 31 Jan.	6^{th} S.W. 7 Feb.	7^{th} S.W. 14 Feb.	8^{th} S.W. 21 Feb.	9^{th} S.W. 28 Feb.	10^{th} S.W. 6 Mar.	11^{th} S.W. 13 Mar.	12^{th} S.W. 20 Mar.	Overall mean
IVT- 521	0.17 (1.082)	0.26 (1.122)	0.29 (1.136)	0.33 (1.153)	0.35 (1.162)	0.87 (1.404)	1.19 (1.480)	1.36 (1.536)	0.97 (1.404)	0.64
IVT- 511	0.05 (1.024)	0.19 (1.091)	0.25 (1.118)	0.29 (1.136)	0.37 (1.17)	0.79 (1.393)	0.96 (1.400)	1.22 (1.490)	0.94 (1.393)	0.56
IVT- 519	0.02 (1.010)	0.11 (1.053)	0.20 (1.095)	0.26 (1.124)	0.26 (1.121)	0.60 (1.261)	0.86 (1.364)	1.11 (1.453)	0.59 (1.261)	0.45
IVT- 501	0.20 (1.095)	0.15 (1.072)	0.35 (1.162)	0.45 (1.204)	0.55 (1.229)	1.15 (1.383)	1.65 (1.628)	1.88 (1.697)	0.92 (1.386)	0.81
IVT - 507	0.1 (1.049)	0.19 (1.091)	0.25 (1.118)	0.35 (1.162)	0.36 (1.166)	0.84 (1.389)	1.19 (1.480)	1.31 (1.520)	0.93 (1.389)	0.61
IVT -506	0.19 (1.091)	0.29 (1.136)	0.38 (1.175)	0.42 (1.192)	0.54 (1.241)	0.92 (1.417)	1.31 (1.520)	1.76 (1.661)	1.01 (1.417)	0.76
IVT -520	0.00 (1.000)	0.00 (1.000)	0.17 (1.082)	0.24 (1.113)	0.27 (1.124)	0.64 (1.241)	0.76 (1.327)	0.98 (1.407)	0.54 (1.241)	0.40
IVT-504	0.00 (1.000)	0.00 (1.000)	0.15 (1.072)	0.36 (1.166)	0.27 (1.127)	0.63 (1.345)	0.82 (1.349)	1.04 (1.428)	0.81 (1.345)	0.59
IVT-517	0.21 (1.100)	0.30 (1.140)	0.25 (1.118)	0.35 (1.162)	0.51 (1.229)	0.95 (1.410)	1.23 (1.493)	1.56 (1.600)	0.99 (1.410)	0.71
IVT -510	0.68 (1.296)	0.42 (1.191)	0.48 (1.216)	0.45 (1.204)	0.68 (1.296)	1.05 (1.414)	1.63 (1.621)	2.06 (1.749)	1.00 (1.414)	0.94
IVT- 516	0.15 (1.072)	0.23 (1.109)	0.27 (1.127)	0.37 (1.170)	0.41 (1.187)	0.85 (1.404)	1.16 (1.470)	1.37 (1.539)	0.97 (1.404)	0.64
IVT- 518	0.05 (1.025)	0.15 (1.072)	0.25 (1.118)	0.29 (1.136)	0.34 (1.158)	0.80 (1.382)	0.97 (1.403)	1.22 (1.490)	0.91 (1.382)	0.55
IVT- 508	0.14 (1.068)	0.19 (1.090)	0.23 (1.109)	0.35 (1.162)	0.38 (1.175)	0.85 (1.360)	1.13 (1.459)	1.28 (1.510)	0.85 (1.360)	0.60
IVT- 513	0.05 (1.025)	0.2 (1.095)	0.20 (1.095)	0.21 (1.098)	0.35 (1.162)	0.75 (1.382)	0.94 (1.392)	1.20 (1.483)	0.91 (1.382)	0.53
IVT- 505	0.00 (1.000)	0.16 (1.077)	0.21 (1.101)	0.26 (1.121)	0.32 (1.149)	0.70 (1.364)	0.91 (1.382)	1.19 (1.48)	0.86 (1.364)	0.51
IVT- 509	0.00 (1.000)	0.00 (1.000)	0.12 (1.092)	0.23 (1.109)	0.24 (1.112)	0.59 (1.323)	0.76 (1.327)	0.95 (1.396)	0.75 (1.323)	0.42
IVT- 503	0.00 (1.000)	0.16 (1.077)	0.21 (1.100)	0.29 (1.135)	0.35 (1.161)	0.69 (1.353)	0.95 (1.396)	1.17 (1.473)	0.83 (1.353)	0.52
IVT- 515	0.22 (1.105)	0.26 (1.122)	0.30 (1.139)	0.37 (1.170)	0.46 (1.208)	0.90 (1.364)	1.17 (1.473)	1.32 (1.523)	0.86 (1.364)	0.65
IVT- 514	0.10 (1.049)	0.16 (1.076)	0.18 (1.086)	0.33 (1.153)	0.32 (1.149)	0.80 (1.389)	1.08 (1.442)	1.25 (1.500)	0.93 (1.389)	0.57
IVT- 512	0.16 (1.077)	0.16 (1.076)	0.22 (1.104)	0.39 (1.164)	0.49 (1.221)	0.87 (1.396)	1.10 (1.449)	1.45 (1.565)	0.95 (1.396)	0.64
IVT- 502	0.18 (1.086)	0.36 (1.166)	0.40 (1.183)	0.51 (1.229)	0.62 (1.272)	1.06 (1.375)	1.56 (1.600)	1.99 (1.729)	0.89 (1.375)	0.84
AVT- 603	0.00 (1.000)	0.11 (1.053)	0.18 (1.101)	0.26 (1.124)	0.29 (1.135)	0.62 (1.261)	0.82 (1.349)	1.08 (1.442)	0.59 (1.261)	0.44
MAL 13*846	0.05 (1.025)	0.11 (1.053)	0.19 (1.090)	0.29 (1.136)	0.32 (1.147)	0.71 (1.311)	0.90 (1.378)	1.13 (1.459)	0.72 (1.311)	0.49
AVT-604	0.02 (1.010)	0.18 (1.086)	0.25 (1.118)	0.32 (1.149)	0.37 (1.169)	0.83 (1.393)	1.08 (1.442)	1.31 (1.52)	0.94 (1.393)	0.45
AVT -607	0.07 (1.034)	0.09 (1.044)	0.16 (1.076)	0.30 (1.139)	0.29 (1.136)	0.76 (1.319)	0.87 (1.367)	1.12 (1.456)	0.74 (1.319)	0.49
AVT-606	0.02 (1.023)	0.07 (1.034)	0.14 (1.067)	0.26 (1.121)	0.26 (1.122)	0.67 (1.292)	0.81 (1.345)	1.08 (1.442)	0.67 (1.292)	0.44
AVT-602	0.13 (1.063)	0.09 (1.044)	0.21 (1.097)	0.38 (1.173)	0.36 (1.166)	0.88 (1.378)	1.24 (1.497)	1.21 (1.487)	0.90 (1.378)	0.40
AVT-601	0.00 (1.000)	0.10 (1.049)	0.15 (1.072)	0.22 (1.104)	0.27 (1.125)	0.66 (1.308)	0.89 (1.375)	1.07 (1.439)	0.71 (1.308)	0.45
AVT-605	0.00 (1.000)	0.02 (1.010)	0.17 (1.082)	0.23 (1.110)	0.30 (1.140)	0.64 (1.277)	0.86 (1.364)	0.94 (1.393)	0.63 (1.277)	0.60
SE(m)±	**0.010**	**0.014**	**0.021**	**0.023**	**0.022**	**0.012**	**0.013**	**0.015**	**0.012**	-
CD at 5%	**0.027**	**0.041**	**0.060**	**0.066**	**0.063**	**0.035**	**0.036**	**0.041**	**0.035**	-

*Figures in parentheses are $\sqrt{x+0.5}$ transformed value; SW = Standard Week

Table 2. Population of blue butterfly, *L. boeticus* on pigeonpea genotypes during *Kharif* 2014-15

Genotypes	Number of maggots per 10 pods*									
	4^{th} S.W. 24 Jan.	5^{th} S.W. 31 Jan.	6^{th} S.W. 7 Feb.	7^{th} S.W. 14 Feb.	8^{th} S.W. 21 Feb.	9^{th} S.W. 28 Feb.	10^{th} S.W. 6 Mar.	11^{th} S.W. 13 Mar.	12^{th} S.W. 20 Mar.	Overall mean
IVT- 521	0.07 (1.034)	0.10 (1.049)	0.19 (1.091)	0.22 (1.104)	0.26 (1.098)	0.31 (1.144)	0.35 (1.161)	0.33 (1.152)	0.28 (1.131)	0.23
IVT- 511	0.05 (1.025)	0.07 (1.034)	0.16 (1.077)	0.20 (1.095)	0.22 (1.104)	0.29 (1.146)	0.37 (1.170)	0.28 (1.131)	0.23 (1.109)	0.21
IVT- 519	0.01 (1.005)	0.04 (1.020)	0.08 (1.039)	0.15 (1.072)	0.18 (1.086)	0.25 (1.095)	0.26 (1.122)	0.27 (1.126)	0.21 (1.100)	0.16
IVT- 510	0.08 (1.039)	0.11 (1.053)	0.21 (1.100)	0.23 (1.108)	0.35 (1.162)	0.33 (1.153)	0.42 (1.192)	0.38 (1.174)	0.29 (1.136)	0.27
IVT - 512	0.00 (1.000)	0.09 (1.044)	0.18 (1.086)	0.21 (1.100)	0.24 (1.113)	0.30 (1.140)	0.32 (1.149)	0.29 (1.136)	0.27 (1.127)	0.21
IVT -502	0.06 (1.029)	0.13 (1.063)	0.20 (1.095)	0.22 (1.104)	0.29 (1.136)	0.38 (1.175)	0.40 (1.183)	0.31 (1.144)	0.31 (1.145)	0.26
IVT -504	0.13 (1.063)	0.14 (1.068)	0.12 (1.058)	0.13 (1.063)	0.13 (1.063)	0.21 (1.100)	0.24 (1.113)	0.15 (1.072)	0.21 (1.100)	0.16
IVT-509	0.00 (1.000)	0.02 (1.010)	0.20 (1.095)	0.18 (1.086)	0.16 (1.077)	0.22 (1.104)	0.26 (1.122)	0.19 (1.090)	0.19 (1.091)	0.16
IVT-517	0.07 (1.034)	0.08 (1.039)	0.23 (1.109)	0.31 (1.144)	0.29 (1.136)	0.33 (1.153)	0.41 (1.187)	0.33 (1.153)	0.24 (1.113)	0.25
IVT -515	0.11 (1.053)	0.06 (1.029)	0.22 (1.104)	0.28 (1.131)	0.30 (1.140)	0.37 (1.170)	0.47 (1.212)	0.41 (1.187)	0.22 (1.104)	0.27
IVT- 516	0.06 (1.029)	0.05 (1.025)	0.19 (1.090)	0.23 (1.109)	0.28 (1.131)	0.31 (1.144)	0.4 (1.183)	0.32 (1.149)	0.23 (1.108)	0.23
IVT- 518	0.04 (1.02)	0.07 (1.034)	0.17 (1.081)	0.21 (1.100)	0.26 (1.122)	0.29 (1.135)	0.37 (1.170)	0.29 (1.136)	0.16 (1.077)	0.21
IVT- 508	0.00 (1.000)	0.02 (1.010)	0.13 (1.063)	0.17 (1.082)	0.21 (1.100)	0.26 (1.122)	0.31 (1.144)	0.18 (1.086)	0.19 (1.091)	0.16
IVT- 513	0.01 (1.005)	0.06 (1.030)	0.15 (1.072)	0.18 (1.086)	0.20 (1.095)	0.25 (1.117)	0.34 (1.157)	0.27 (1.127)	0.24 (1.113)	0.19
IVT- 505	0.09 (1.044)	0.13 (1.063)	0.16 (1.076)	0.16 (1.077)	0.22 (1.104)	0.26 (1.105)	0.33 (1.153)	0.26 (1.122)	0.17 (1.082)	0.20
IVT- 520	0.03 (1.015)	0.02 (1.010)	0.09 (1.044)	0.13 (1.079)	0.18 (1.085)	0.20 (1.095)	0.26 (1.122)	0.21 (1.100)	0.25 (1.118)	0.15
IVT- 503	0.07 (1.034)	0.13 (1.063)	0.12 (1.058)	0.12 (1.058)	0.21 (1.098)	0.29 (1.135)	0.32 (1.149)	0.26 (1.122)	0.18 (1.085)	0.19
IVT- 506	0.00 (1.000)	0.05 (1.025)	0.20 (1.095)	0.25 (1.118)	0.25 (1.118)	0.30 (1.140)	0.41 (1.187)	0.33 (1.153)	0.16 (1.077)	0.22
IVT- 514	0.07 (1.034)	0.12 (1.058)	0.14 (1.067)	0.18 (1.086)	0.20 (1.095)	0.24 (1.114)	0.36 (1.166)	0.25 (1.118)	0.15 (1.072)	0.19
IVT- 507	0.10 (1.049)	0.10 (1.049)	0.16 (1.077)	0.24 (1.113)	0.24 (1.113)	0.27 (1.091)	0.32 (1.149)	0.20 (1.095)	0.18 (1.086)	0.20
IVT- 501	0.11 (1.053)	0.06 (1.030)	0.19 (1.091)	0.27 (1.127)	0.31 (1.145)	0.36 (1.166)	0.36 (1.166)	0.37 (1.170)	0.30 (1.140)	0.26
AVT- 601	0.07 (1.034)	0.04 (1.020)	0.08 (1.039)	0.18 (1.086)	0.24 (1.113)	0.28 (1.131)	0.33 (1.153)	0.29 (1.136)	0.31 (1.144)	0.20
MAL 13*846	0.00 (1.000)	0.05 (1.025)	0.13 (1.063)	0.14 (1.068)	0.20 (1.095)	0.24 (1.114)	0.32 (1.145)	0.27 (1.127)	0.26 (1.122)	0.18
AVT-604	0.08 (1.039)	0.03 (1.015)	0.10 (1.049)	0.12 (1.058)	0.16 (1.077)	0.22 (1.105)	0.29 (1.135)	0.23 (1.109)	0.27 (1.126)	0.17
AVT -607	0.03 (1.016)	0.00 (1.000)	0.14 (1.068)	0.18 (1.086)	0.17 (1.111)	0.22 (1.104)	0.31(1.144)	0.24 (1.113)	0.25 (1.118)	0.17
AVT-606	0.06 (1.03)	0.04 (1.020)	0.11 (1.053)	0.15 (1.072)	0.18 (1.086)	0.24 (1.113)	0.22 (1.104)	0.22 (1.104)	0.28 (1.131)	0.17
AVT-602	0.05 (1.025)	0.09 (1.044)	0.18 (1.086)	0.21 (1.100)	0.24 (1.110)	0.30 (1.14)	0.31(1.144)	0.30 (1.140)	0.14 (1.068)	0.20
AVT-603	0.02 (1.010)	0.04 (1.020)	0.12 (1.058)	0.14 (1.068)	0.17 (1.081)	0.22 (1.104)	0.27 (1.127)	0.25 (1.118)	0.22 (1.104)	0.16
AVT-605	0.03 (1.015)	0.12 (1.058)	0.10 (1.049)	0.19 (1.091)	0.25 (1.118)	0.26 (1.122)	0.33 (1.153)	0.30 (1.140)	0.32 (1.149)	0.21
SE(m)±	**0.011**	**0.010**	**0.015**	**0.013**	**0.014**	**0.015**	**0.019**	**0.019**	**0.017**	-
CD at 5%	**0.030**	**0.028**	**0.043**	**0.037**	**0.038**	**0.042**	**0.054**	**0.054**	**0.048**	-

*Figures in parentheses are $\sqrt{x+0.5}$ transformed value; SW = Standard Week

who reported that the activity of pod borer (*Helicoverpa armigera*) infestation was observed from 23rd January to 8th April. Its peak population was recorded on 24th March. Dhar *et al.* (2008) also reported that rainfall during 1-9 standard weeks along with a considerable adult *H. armigera* population (> 15 per week) during 5-7 standard weeks triggered a major rise in the population of this insect on pigeonpea during 10-14 standard weeks.

Blue butterfly (*Lampides boeticus*)

During 2014-15, the first incidence of blue butterfly, *L. boeticus* was observed in 4th standard week in all genotypes except IVT-512, IVT-509, IVT-508, IVT-506, AVT (MAL13*846), AVT-603, AVT-607, AVT-606, AVT-602 and AVT-601 in which population was observed from 5th standard week. The peak population of *L. boeticus* was observed between 10th to 11th standard weeks in different genotypes. The highest and lowest populations were observed in the 10th and 4th standard week, respectively. Among the twenty nine genotypes/varieties, the mean population of blue butterfly was recorded highest in genotype IVT-510 (0.27 larvae/plant), followed by IVT-502, IVT-501 (0.26 larvae/plant), and lowest in genotype *i.e.* IVT-520 (0.15 larvae/plant) followed by IVT-509, (0.16 larvae/plant) AVT-602 (0.19 larvae/plant) (Table 2). Shantibala *et al.* (2004) also reported that *L. boeticus* attacked the pigeonpea crop with the onset of flowering during second fortnight of November and remained in the field till crop maturity. Kumar and Nath (2005) also found the average population of 1.31 larvae of *L. boeticus* per 5 pigeonpea plants in a study conducted during 1994-96.

Plume moth (*Exelastis atomosa*)

During 2014-15, the first incidence of plume moth, *E. atomosa* was observed on 4th standard week in all genotypes except IVT-519, IVT-512, IVT-520, IVT-518, IVT-508, IVT-513, IVT-509, IVT-503, AVT (MAL13*846), AVT-603, AVT-607, AVT-606, AVT-602, AVT-601 in which first incidence observed on 5th standard week except IVT-520, IVT-509. The peak population of plume moth was observed in 11th standard week on all genotypes except IVT-512, IVT-514, IVT-502, AVT-(MAL 13*846) AVT-603, AVT-607, AVT-606, AVT-602, AVT-601 in which peak was observed on 12th standard week. The mean population of plume moth differed significantly among genotypes and ranged from 0.19 larvae/ plant in IVT-520 to 0.56 larvae/ plant in IVT-510 (Table 3). Kumar and Nath (2005) also reported the average population of *Exelastis atomosa* as 0.92 larvae plants^{-5} on pigeonpea at Varanasi. Chavan *et al.* (2010) also conducted field studies to determine the resistance of 11 pigeonpea genotypes against *E. atomosa.*

Extent of damage caused by lepidopteran pod borers in different pigeonpea genotypes

The data presented in table 4 depicted the per cent pod damage and grain damage by pod bug on different pigeonpea genotypes during 2014-15. The per cent pod damage due to lepidopteran pod borers on different genotypes varied significantly. It ranged from 4.33 per cent in genotype IVT-520 to 11.67 per cent in genotype IVT-502. Maximum pod damage due to pod bug were seen in IVT-502 (11.67%) followed by IVT-510 (11.33%) and IVT-501 (9.67%) and lowest pod damage was observed in IVT-520 (4.33%) followed by IVT-509 (5.00%) and AVT-603 (7.00%). The per cent grain damage due to lepidopteran pod borers also showed significant differences among the genotypes. It ranged from 1.07 per cent in genotype IVT-520 to 4.90 per cent in genotype IVT-510. The highest grain damage by lepidopteran pod borers were seen in IVT-510 *i.e.* (4.90%) followed by IVT-502 (3.72%), IVT-501(2.98%) and lowest grain damage was observed in IVT-520 (1.07%) followed by IVT 509 (1.48%) and AVT-603 (1.83%).

The present findings are in partial agreement with Srivastava and Mohapatra (2002) who conducted an experiment where fifteen medium duration pigeonpea genotypes were examined and the pest susceptible rating (PSR) showed that the genotype ICP 8863 suffered the highest pod damage caused by lepidopteran pod borers, while the lowest was in KM 124 and KM 125. Khan *et al.* (2014) also screened twenty four genotypes of pigeonpea at Varanasi and found genotypes ICP 10531, ICP 13212, ICPL 20036, ICPHaRL 4979-2 and ICPHaRL 4985-1 most

TABLE 3. Population of plume moth, *E. atomosa* on pigeonpea genotypes during *Kharif* 2014-15

Genotypes	Number of maggots per 10 pods*									
	4th S.W. 24 Jan.	5th S.W. 31 Jan.	6th S.W. 7 Feb.	7th S.W. 14 Feb.	8th S.W. 21 Feb.	9th S.W. 28 Feb.	10th S.W. 6 Mar.	11th S.W. 13 Mar.	12th S.W. 20 Mar.	Overall mean
IVT- 521	0.04 (1.020)	0.13 (1.063)	0.15 (1.072)	0.27 (1.127)	0.34 (1.157)	0.4 (1.183)	0.50 (1.225)	0.63 (1.277)	0.60 (1.265)	0.34
IVT- 511	0.07 (1.034)	0.07 (1.034)	0.12 (1.058)	0.19 (1.091)	0.25 (1.118)	0.35 (1.161)	0.45 (1.204)	0.60 (1.264)	0.51 (1.229)	0.29
IVT- 519	0.00 (1.000)	0.03 (1.015)	0.07 (1.034)	0.14 (1.068)	0.2 (1.095)	0.22 (1.104)	0.36 (1.166)	0.50 (1.225)	0.44 (1.200)	0.22
IVT- 501	0.10 (1.049)	0.19 (1.091)	0.28 (1.131)	0.35 (1.162)	0.45 (1.204)	0.57 (1.253)	0.81 (1.345)	0.99 (1.411)	0.89 (1.375)	0.51
IVT - 512	0.00 (1.000)	0.13 (1.063)	0.18 (1.086)	0.19 (1.091)	0.29 (1.135)	0.33 (1.153)	0.51 (1.229)	0.67 (1.292)	0.70 (1.304)	0.33
IVT -515	0.10 (1.049)	0.15 (1.072)	0.23 (1.109)	0.35 (1.162)	0.49 (1.220)	0.53 (1.237)	0.68 (1.296)	0.88 (1.371)	0.79 (1.338)	0.47
IVT -520	0.00 (1.000)	0.00 (1.000)	0.05 (1.025)	0.12 (1.058)	0.13 (1.063)	0.20 (1.095)	0.36 (1.166)	0.47 (1.212)	0.37 (1.170)	0.19
IVT-504	0.05 (1.025)	0.13 (1.063)	0.16 (1.077)	0.20 (1.095)	0.27 (1.127)	0.35 (1.162)	0.47 (1.215)	0.64 (1.280)	0.57 (1.256)	0.32
IVT-517	0.10 (1.049)	0.07 (1.034)	0.12 (1.058)	0.32 (1.149)	0.43 (1.196)	0.53 (1.237)	0.78 (1.334)	0.69 (1.300)	0.76 (1.327)	0.42
IVT -510	0.18 (1.086)	0.12 (1.058)	0.28 (1.131)	0.40 (1.183)	0.54 (1.241)	0.66 (1.288)	0.87 (1.37)	1.08 (1.442)	0.93 (1.389)	0.56
IVT- 516	0.07 (1.034)	0.20 (1.095)	0.13 (1.063)	0.22 (1.104)	0.2 (1.095)	0.44 (1.200)	0.66 (1.288)	0.76 (1.339)	0.60 (1.264)	0.36
IVT- 518	0.00 (1.000)	0.07 (1.034)	0.13 (1.063)	0.18 (1.086)	0.25 (1.103)	0.35 (1.162)	0.54 (1.241)	0.58 (1.257)	0.51 (1.229)	0.29
IVT- 508	0.00 (1.000)	0.02 (1.030)	0.07 (1.034)	0.15 (1.072)	0.21 (1.100)	0.27 (1.127)	0.39 (1.179)	0.49 (1.221)	0.45 (1.204)	0.23
IVT- 513	0.00 (1.000)	0.07 (1.034)	0.1 (1.049)	0.16 (1.077)	0.24 (1.113)	0.31 (1.144)	0.43 (1.196)	0.63 (1.277)	0.56 (1.249)	0.28
IVT- 505	0.00 (1.000)	0.05 (1.025)	0.12 (1.058)	0.17 (1.082)	0.25 (1.118)	0.31 (1.144)	0.39 (1.179)	0.53 (1.237)	0.49 (1.219)	0.26
IVT- 509	0.00 (1.000)	0.00 (1.000)	0.13 (1.063)	0.14 (1.068)	0.20 (1.095)	0.20 (1.095)	0.37 (1.170)	0.49 (1.221)	0.38 (1.175)	0.21
IVT- 503	0.00 (1.000)	0.05 (1.025)	0.12 (1.058)	0.20 (1.095)	0.18 (1.086)	0.29 (1.136)	0.43 (1.196)	0.59 (1.261)	0.50 (1.225)	0.26
IVT- 506	0.07 (1.034)	0.20 (1.095)	0.15 (1.072)	0.35 (1.162)	0.30 (1.140)	0.45 (1.204)	0.57 (1.254)	0.76 (1.327)	0.61 (1.269)	0.38
IVT- 514	0.05 (1.024)	0.13 (1.063)	0.12 (1.058)	0.22 (1.104)	0.23 (1.109)	0.31 (1.144)	0.60 (1.265)	0.59 (1.261)	0.66 (1.288)	0.32
IVT- 507	0.13 (1.063)	0.10 (1.048)	0.30 (1.140)	0.25 (1.118)	0.24 (1.113)	0.49 (1.221)	0.58 (1.259)	0.73 (1.316)	0.82 (1.350)	0.40
IVT- 502	0.20 (1.095)	0.39 (1.179)	0.28 (1.131)	0.39 (1.179)	0.39 (1.179)	0.60 (1.265)	0.81 (1.345)	0.97 (1.404)	0.98 (1.407)	0.56
AVT- 604	0.14 (1.068)	0.19 (1.091)	0.12 (1.058)	0.33 (1.153)	0.33 (1.153)	0.42 (1.191)	0.49 (1.221)	0.65 (1.284)	0.63 (1.277)	0.37
MAL 13*846	0.00 (1.000)	0.13 (1.063)	0.13 (1.063)	0.16 (1.077)	0.15 (1.072)	0.30 (1.140)	0.41 (1.187)	0.54 (1.241)	0.60 (1.265)	0.27
AVT-603	0.00 (1.000)	0.05 (1.025)	0.00 (1.000)	0.15 (1.072)	0.23 (1.109)	0.23 (1.108)	0.34 (1.158)	0.46 (1.208)	0.51 (1.229)	0.22
AVT -607	0.00 (1.000)	0.07 (1.034)	0.10 (1.049)	0.16 (1.077)	0.15 (1.072)	0.27 (1.126)	0.37 (1.169)	0.56 (1.249)	0.57 (1.256)	0.25
AVT-606	0.00 (1.000)	0.09 (1.044)	0.00 (1.000)	0.15 (1.072)	0.16 (1.092)	0.29 (1.136)	0.39 (1.178)	0.43 (1.196)	0.53 (1.237)	0.23
AVT-602	0.00 (1.000)	0.07 (1.034)	0.00 (1.000)	0.13 (1.063)	0.11 (1.053)	0.17 (1.082)	0.29 (1.136)	0.37 (1.170)	0.54 (1.241)	0.19
AVT-601	0.00 (1.000)	0.11 (1.054)	0.09 (1.044)	0.11 (1.053)	0.13 (1.063)	0.26 (1.122)	0.34 (1.157)	0.49 (1.221)	0.74 (1.319)	0.25
AVT-605	0.15 (1.072)	0.19 (1.091)	0.15 (1.072)	0.28 (1.131)	0.18 (1.086)	0.48 (1.216)	0.45 (1.204)	0.69 (1.300)	0.49 (1.212)	0.34
SE(m)±	0.007	0.010	0.011	0.009	0.018	0.016	0.017	0.014	0.012	-
CD at 5%	0.020	0.029	0.032	0.026	0.051	0.045	0.047	0.040	0.035	-

*Figures in parentheses are $\sqrt{x+0.5}$ transformed value; SW = Standard Week

TABLE 4. Extent of damage caused by lepidopteran pod borers and yield of different long duration pigeonpea genotypes during 2014-15

Genotypes	% Pod Damage*	% Grain Damage*	Yield (kg/ha)
IVT- 519	6.33 (14.93)	3.12 (9.75)	2504
IVT- 511	6.67 (14.78)	2.75 (9.30)	1992
IVT- 508	5.33 (13.07)	1.56 (7.05)	2166
IVT- 512	7.33 (15.66)	3.27 (10.40)	1304
IVT- 514	7.00 (15.25)	3.72 (10.99)	2592
IVT- 513	7.67 (15.93)	2.54 (9.14)	2295
IVT- 516	5.67 (13.61)	2.23 (8.55)	2083
IVT- 517	8.67 (17.10)	2.75 (9.51)	2381
IVT- 501	9.67 (18.08)	2.98 (9.93)	1300
IVT- 520	4.33 (11.98)	1.07 (5.93)	3314
IVT- 515	8.33 (16.75)	1.91 (7.93)	2268
IVT- 518	8.67 (17.41)	2.01 (8.04)	2652
IVT- 521	8.00 (16.40)	2.47 (9.01)	2674
IVT- 505	6.67 (14.95)	2.41 (8.89)	1698
IVT- 509	5.00 (12.83)	1.48 (6.98)	3199
IVT- 504	7.33 (15.66)	2.39 (8.46)	2801
IVT- 503	10.33 (18.68)	3.12 (10.11)	2775
IVT- 506	9.67 (18.09)	2.89 (9.77)	2836
IVT- 502	11.67 (19.95)	3.72 (11.10)	1244
IVT- 507	8.00 (16.41)	3.10 (10.12)	1725
IVT- 510	11.33 (19.61)	4.90 (12.65)	479
AVT-602	9.33 (17.76)	2.05 (8.21)	2164
MAL 13*846	10.67 (19.04)	3.09 (10.12)	2293
AVT- 604	8.33 (16.74)	2.98 (9.83)	2752
AVT- 603	7.00 (15.44)	1.83 (7.75)	3196
AVT- 606	9.00 (17.44)	2.90 (9.73)	2025
AVT- 607	8.33 (16.76)	2.89 (9.76)	2994
AVT-601	10.00 (18.36)	3.03 (9.97)	2393
AVT- 605	7.67 (16.07)	2.50 (9.06)	2395
SE(m)±	**0.931**	**0.801**	–
CD at 5%	**2.646**	**2.275**	–

*Figures in parentheses are arc sin transformed values susceptible against pod borers, as they exhibited damage rating of 8 on Pest Susceptibility Rating Index. Rathod *et al.* (2014) reported that among the genotypes of pigeonpea screened, BSMR-853 recorded lower per cent pod damage due to pod borer (18.59 %) which was at par with AGT-2 (20.9 %). The highest pod damage was recorded on variety ICPL – 87119 (36.56 %).

Grain yield

The data on grain yield per hectare of different genotypes are given in Table 3. There was significant difference in grain yield among the genotypes. The highest grain yield was recorded from IVT 520 (3314 kg/ha) which was significantly different from other genotypes where as the lowest grain yield was recorded from IVT-510 (479 kg/ha). These findings are in conformity with Khan *et al.* (2014) and Borad *et al.* (1991) who also reported higher yield potential in those pigeonpea genotypes which showed lesser incidence of pod borers.

On the basis of the above investigation it may be concluded that host plant resistance plays a very important part in governing the pest infestation level in pigeonpea and screening is an appropriate method to identify resistant genotypes. The lepidopteran pod borers, *H. armigera*, *L. boeticus* and *E. atomosa* are cardinal insect pests on pigeonpea in this zone and its incidence increases with the advancement of crop age. Actual damage to the economic produce also takes place after flowering in case of pulses. Among the twenty nine genotypes screened, IVT-520, IVT-509 and AVT-603 were found to be most resistant against pod borer damage and hence should be promoted among the farmers.

Literature Cited

Anonymous. 2014. *Agricultural statistics at a glance*, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, p. 97.

Borad, P. K., Patel, J. R., Patel, M. G. 1991. Evaluation of vegetable pigeonpea genotypes resistance to gram pod borer, plume moth and pod fly. Indian J. Agric. Sci., 61, 682-684.

Chavan, A. P., Bramhane, R. O., Shinde, V. B. and Harer, P. N. 2010. Resistance against pod borer complex in pigeonpea. J. Maharashtra Agric. Univ., 35, 469-470.

Dhar, V., Singh, S. K., Trivedi, T. P., Das, O. K., Dhandapani, A. and Chaudhary,R. G. 2008. Forecasting of *Helicoverpa armigera* infestation on long duration in central Uttar Pradesh. J. Food Leg., 21, 189-192.

Gopali, J. B., Teggelli, R. D., Mannur, M. and Yelshetty, S. 2010. Web-forming lepidopteran, *Maruca vitrata* (Geyer): an emerging and destructive pest in pigeonpea. Karnataka J. Agric. Sci., 23, 35-38.

Khan, M., Srivastava, C. P. and Sitanshu. 2014. Screening of some promising pigeonpea genotypes against major insect pests. The Ecoscan., 6, 313-316.

Kumar, A. and Nath, P. 2003. Pest complex and their population dynamics on medium-late variety of pigeonpea Bahar. Indian J. Pulses Res., 16, 150-154.

Kumar, A. and Nath, P. 2005. Study of the effect of meteorological factors on the population of insect pests infesting UPAS 120 cultivar of pigeonpea. *J. Maharashtra Agric. Univ.,* 30, 190-192.

Mathukia, R. K., Ponkia, H. P. and Polara, A. M. 2016. In situ conservation and zinc fertilization for rainfed pigeonpea (*Cajanus cajan* L.). The Bioscan., 11, 247-250.

Rathod, N. P., Vala, G. S., Dudhal, A. S. and Kachhadiya, N. M. 2014. Screening of different varieties of pigeonpea against pod borer complex. Int. J. Plant Prot., 7, 154-156.

Shantibala, T., Subharani, S. and Singh, T. K. 2004. Seasonal incidence of *Lampidesboeticus* (Linnaeus) and influence of weather factors on its abundance on, *Cajanuscajan* (L.) Millsp.In Manipur. Indian J. Entomol., 66, 198-201.

Srilaxmi, K. and Paul, R. 2010. Diversity of insect pests of pigeonpea [*Cajanus cajan* (L.) Millsp.] and their succession in relation to crop phenology in Gulbarga, Karnataka. The Ecoscan., 4, 273-276.

Srivastava, C. P. and Mohapatra, S. D. 2002. Field screening of genotypes for resistance to major insect pests. J. Appl. Zool. Res., 13, 202-203.

Sujithra, M. and Chander, S. 2014. Seasonal incidence and damage of major insect pests of pigeonpea, *Cajanus cajan* (L.). Indian J. Entomol., 76, 202-206.

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Yield Potential and Economics of Elephant Foot Yam (*Amorphophallus Paeoniifolius*) as Influenced by Fertility Levels, Light Interception and Soil Resistance

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Abstract

Evaluation of yield related traits of commercial crop elephant foot yam under varied nutrient regimes showed that the light interception percentage was encountered maximum in FYM @ 25 t ha^{-1} (71.2%) and minimum was recorded in control plot viz. 46.2%. The soil resistance was also found to be maximum in 100-60-100 N-P_2O_5-K_2O kg ha^{-1} (0.446 MPa) and minimum was recorded in FYM @ 25 t ha^{-1} (0.231 MPa). The mean data revealed that treatment with FYM 10 t ha^{-1} + 100-60-100 N-P_2O_5-K_20 kg ha^{-1} also exerted its significant influence on the corm yield per plant with highest corm yield (2150g) followed by FYM @ 25 t ha^{-1} (2060g) and FYM @ 10 t ha^{-1} +80-60-80 N-P_2O_5-K_20 kg ha^{-1} (2020 g). The highest gross and net returns as well as benefit cost ratio were recorded in FYM 10 t ha^{-1} + 100-60-100 N-P_2O_5-K_20 kg ha^{-1}.

Introduction

Elephant foot yam *(Amorphophallus paeoniifolius)* which is regarded as "King of Tuber crop" and gaining rapid momentum as a high value tuber crop due to its high yield and minimum input utilization along with prolonged period of storage makes it an ideal crop for livelihood security.The crop geometry and plant architecture in tuber crops especially in elephant foot yam is an upper ground operation intending to harness maximum light interception with a differential flow of assimilates leads to enhanced biomass production and has a direct influence on yield. Light interception efficiency is a crucial determinant of carbon uptake by individual plants and by vegetation and subsequently soil resistance plays a pivotal role for tuber bulking resulting in better yield. Our aim was to identify the role of light interception and soil resistance that summarize yield potential.

Materials and Methods

The field experiment was carried out for consecutive two years during 2011 and 2012 at Regional Centre of Central Tuber crops Research Institute (20˚14'53.25" N and 85˚47'25.85"E and 33 m above mean sea level), Dumduma, Bhubaneswar, Odisha, India. Texturally the soil was sandy loam with neutral soil reaction (p^H 6.7). The soil type of experimental site was alfisols and comes under the family "Typic Rhodustalfs". The initial soil fertility status of the experimental site was 0.3% organic carbon, 91.5 kg ha^{-1} available nitrogen, 14.9 kg ha^{-1} available phosphorus and 235.7 kg ha^{-1} available potassium. The mean maximum and minimum temperatures ranged between 29.4-38.3˚C and 15.4-26.6˚C respectively and mean maximum and minimum relative humidity varied in between 61.5-90.7%. The average rainfall was 1273.9 mm and precipitation was higher during June to September over both the experimental years. The experimental plot was divided into 24 plots with eight plots per row. Corms of cv. Gajendra were planted on ridges or hills with a plant to plant spacing of 75 cm and ridge to ridge spacing of 75 cm. The experiment was laid out in randomized block design (RBD) having three replicates. The experiment comprised of eight treatments viz. T_1- Control, T_2 - 60-60-60 N-P_2O_5-$K_2$0 kg ha^{-1}, T_3 - 80-60-80 N-P_2O_5-$K_2$0 kg ha^{-1}, T_4 - 100-60-100 N-P_2O_5-$K_2$0 kg ha^{-1}, T_5 - FYM 10 t ha^{-1} +60-60-60 N-P_2O_5-$K_2$0 kg ha^{-1}, T_6 – FYM @ 10 t ha^{-1} +80-60-80 N-P_2O_5-$K_2$0 kg ha^{-1}, T_7 - FYM 10 t ha^{-1} + 100-60-100 N-P_2O_5-$K_2$0 kg ha^{-1} and T_8 – FYM @ 25 t ha^{-1}. Full P was applied as basal dose during the final ploughing and 1/3rd of N and K were applied in two equal splits at one and two months after planting. The FYM used in this experiment contained 0.54% N, 0.32% P and 0.48% K.

Light measurements above and below the canopy were taken at 3 and 5 months after planting (MAP) with digital light meter (LX-101A; Lutron Electronic Enterprise Co., Ltd). The difference of light measurement above and below canopy was multiplied with 100 and expressed in percentage of light interception. Soil resistance was measured with penetrologger (Eijkelkamp, The Netherlands) at 3 and 5 MAP and expressed in MPa. Effect of fertility levels on yield attributes and yield of elephant foot yam (Pooled mean of 2 years) in terms of corm diameter (cm), corm yield as Corm bulking rate (CBR) and Corm Bulking Efficiency (CBE) were worked out as per standard protocol.Observations were recorded on completion of 3rd,5th and 8th month of planting (MAP). The Cost benefit analysis was done on gross and net return keeping total cost of cultivation as the base line.

Results and Discussion

Effect of fertility levels on light interception and soil resistance

Light interception (%)

Light interception through the canopy system was significantly influenced by varied fertility levels on the tuber crop elephant foot yam cv. Gajendra as evident in Table 1. After 3 months of planting, highest light interception was recorded in T_8 (54.05%) followed by T_7 (50.60%) and T_6 (45.60%). The lowest light interception was attained in treatment T_1 (29.85%) owing to its minimum canopy spread. Rest of the treatments had moderate light interception ranging from 38.60% to 38.20%. A similar trend was also recorded at 5 months after planting with highest light interception in T_8 (71.20%) followed by T_7 (66.75%), T_6 (65.35%), T_5 (65.35%) and T_4 (65.35%).The lowest light interception was found in T_1 (46.2%). Better light interception in the treatments T_8, T_7 and T_6 may be due to better growth parameters like plant height, canopy spread and maximum leaflets per plant. Similarly, as the fertilizer levels were increased, higher vegetative growth was perceived with higher interception of solar radiation on the canopy and least

Table 1. Effect of fertility levels on light interception and soil resistance of elephant foot yam

Treatments	Light interception (%)		Soil resistance (MPa)	
	3 MAP	5 MAP	3 MAP	5 MAP
T_1	29.85	46.2	0.399	0.385
T_2	33.60	60.25	0.421	0.405
T_3	36.90	60.15	0.426	0.438
T_4	37.85	65.35	0.438	0.446
T_5	38.20	65.35	0.351	0.308
T_6	45.60	65.35	0.338	0.306
T_7	50.60	66.75	0.331	0.285
T_8	54.05	71.20	0.288	0.231
SEm±	1.401	1.991	0.008	0.010
CD (5%)	4.09	5.81	0.023	0.031

Note: T_1- Control, T_2 - 60-60-60 N-P_2O_5-$K_2$0 kg ha^{-1}, T_3 - 80-60-80 N-P_2O_5-$K_2$0 kg ha^{-1}, T_4 - 100-60-100 N-P_2O_5-$K_2$0 kg ha^{-1}, T_5 - FYM 10 t ha^{-1} +60-60-60 N-P_2O_5-$K_2$0 kg ha^{-1}, T_6 – FYM @ 10 t ha^{-1} +80-60-80 N-P_2O_5-$K_2$0 kg ha^{-1}, T_7 - FYM 10 t ha^{-1} + 100-60-100 N-P_2O_5-$K_2$0 kg ha^{-1} and T_8 – FYM @ 25 t ha^{-1} MAP: Months after planting.

radiation being passed on to the ground. This might be attributed to better interception and absorption of photons by photosynthetic organs, which regulated photosynthetic tissue equally on both sides of a leaf (isobilateral) to maximise use of light absorbed from either side, or preferentially on one side (dorsiventral), which ultimately involved utilisation or dissipation of quantum energy so derived by which the available solar radiation was used for active growth and storage sinks for better growth and development (Loomis and Williams, 1969). Similar views were ushered by Sethi *et al.*, 2002 and Choudhary *et al.*, 2006.

Soil resistance (MPa)

The favourable soil condition for optimum crop growth with soil resistance expressed as MPa, the results of which are detailed in Table 1. After 3 months of planting, the minimum soil resistance was recorded in treatment T_8 (0.288) followed by T_7 (0.331) and T_6 (0.338), all the three having nearly equal effect. Maximum soil resistance was noticed in T_4 (0.438) that had the highest dosage of fertilizer followed by T_3 (0.426) and T_2 (0.421). After 5 months of planting, treatment T_8 exerted minimum soil resistance (0.231) followed by T_7 (0.285) and T_6 (0.306) with statistically comparable effect. The treatments having sole application of chemical fertilizers exerted higher soil resistance ranging from 0.405 to 0.446 indicating a favourable effect of organic manure on soil conditions. The higher corm yield might be due to less soil resistance in T_8 and sole application of FYM @ 25 t ha^{-1}, which enhanced the soil conditioning and provided better platform for better growth and development of corm. As reported by Stockdale *et al.* (2001), the improvement in soil physical condition can be attributed to the increase in soil organic matter content, which dilutes the denser fractions of soil, reduces the strength of the surface crusts, favours the formation of stable soil aggregates especially macro soil aggregate stability and macro porosity which later on confers a platform for less soil resistance leading to better yield of crop.

Effect of soil resistance on corm production of elephant foot yam

Corm diameter (cm)

The effect of differential fertility levels on the yield and yield attributes of elephant foot yam study during 2011 and 2012 has been depicted in Table 2. The pooled mean data for both the years of investigation revealed that treatment T_7 resulted in highest corm diameter (25.55 cm) closely followed by T_8 (24.65 cm), T_6 (24.50 cm) and T_5 (23.40 cm). Minimum corm diameter was observed in T_1 (19.55 cm). Treatment T_2 did not differ significantly from the control. The four treatments viz. T_7, T_8, T_6 and T_5 were statistically at par with each other which might be due to conjoint application of organic manure with chemical fertilizer at its optimum level. The range of values was in accordance with Das *et al.* (1997).

Corm Yield (g plant^{-1})

The mean data presented in Table 2 revealed that treatment T_7 also exerted its significant influence on the corm yield per plant with highest corm yield (2150g) followed by T_8 (2060g), T_6 (2020 g), T_5 (1845 g) and T_4 (1695 g). As expected, elephant foot yam plant having no fertility supplements i.e. T_1 (control) produced the lowest corm yield (1045 g). The corm yield increased gradually with increase in fertility levels and the same trend of fertilizer response was reported in yam (Nwinyi, 1985) as well as in taro (Ramaswamy *et al.,* 1982) and in elephant foot yam (Mukhopadhyay and Sen, 1986). The increase in yield was about 97.12 % (T_8) and 105.74% (T_7) over control (T_1). Higher yield in T_7 and T_8 may be ascribed to the substantially higher canopy spread, corm bulking rate and total biomass production in this variety which could provide better translocation of photosynthates from source to sink, resulting in higher corm weight. The range values were comparable to observations of Suja *et al.* (2010).

Corm bulking rate (CBR) (g day^{-1})

The influence of different treatments on corm bulking rate measured in g day^{-1} indicated that up to 3 MAP, treatment T_7 recorded highest corm bulking rate (8.32 g day^{-1}) followed by T_8 (7.95 g day^{-1}), T_6 (7.81 g day^{-1}) and T_5 (6.58 g day^{-1}) with nearly equal statistical effect. In contrast, T_1 had very slow corm bulking rate (3.56 g day^{-1}). A similar trend of CBR was also noticed in 3-5 MAP and 5-8 MAP (Table 2).

Table 2. Effect of fertility levels on yield attributes and yield of elephant foot yam (Pooled mean of 2 years)

Treatments	Corm diameter (cm)	Corm yield (gplant^{-1})	CBR (g day^{-1}) 0-3 MAP	CBR 3-5 MAP	CBR 5-8 MAP	CBE (%) 0-3 MAP	CBE 3-5 MAP	CBE 5-8 MAP	Corm yield (t ha^{-1})
T_1	19.55	1045	3.56	4.96	5.58	9.00	54.5	161.25	18.3
T_2	20.60	1390	4.83	5.94	6.23	20.88	98.12	247.50	24.3
T_3	21.60	1555	5.15	6.89	7.11	26.37	129.75	288.75	27.2
T_4	23.00	1695	5.85	7.51	7.94	31.75	141.12	323.75	29.6
T_5	23.40	1845	6.58	7.89	8.75	48.12	166.50	361.25	32.3
T_6	24.50	2020	7.81	8.47	8.98	75.75	202.88	405.00	35.4
T_7	25.55	2150	8.32	9.11	9.49	87.25	224.00	437.50	37.6
T_8	24.65	2060	7.95	8.98	9.00	78.87	212.38	415.00	36.1
SEm±	0.651	42	0.102	0.171	0.171	1.782	4.829	10.988	0.71
CD (5%)	1.90	124	0.29	0.50	0.50	5.20	14.10	32.08	2.1

Note: T_1- Control, T_2 - 60-60-60 N-P_2O_5-K_20 kg ha^{-1}, T_3 - 80-60-80 N-P_2O_5-K_20 kg ha^{-1}, T_4 - 100-60-100 N-P_2O_5-K_20 kg ha^{-1}, T_5 - FYM 10 t ha^{-1} +60-60-60 N-P_2O_5-K_20 kg ha^{-1}, T_6 – FYM @ 10 t ha^{-1} +80-60-80 N-P_2O_5-K_20 kg ha^{-1}, T_7 - FYM 10 t ha^{-1} + 100-60-100 N-P_2O_5-K_20 kg ha^{-1} and T_8 – FYM @ 25 t ha^{-1} MAP: Months after planting.

Table 3. Cost benefit analysis of the experimental setup

Treatments	Cost of cultivation (Rs)	Gross return (Rs.)	Net return (Rs.)	B:C ratio (Rs.)
T_1	1,58,150	1,83,000	24,850	1.15
T_2	1,67,366	2,24,300	56,934	1.34
T_3	1,69,742	2,27,200	57,458	1.33
T_4	1,71,920	2,96,000	1,24,080	1.72
T_5	1,83,366	3,23,000	1,39,634	1.76
T_6	1,84,842	3,54,000	1,69,158	1.91
T_7	1,87,290	3,76,000	1,88,710	2.00
T_8	1,97,050	3,61,000	1,63,950	1.83
SEm ±	5565	9424	2542	0.041
CD (5%)	16250	27520	7424	0.12

Note: T_1- Control, T_2 - 60-60-60 N-P_2O_5-K_20 kg ha^{-1}, T_3 - 80-60-80 N-P_2O_5-K_20 kg ha^{-1}, T_4 - 100-60-100 N-P_2O_5-K_20 kg ha^{-1}, T_5 - FYM 10 t ha^{-1} +60-60-60 N-P_2O_5-K_20 kg ha^{-1}, T_6 – FYM @ 10 t ha^{-1} +80-60-80 N-P_2O_5-K_20 kg ha^{-1}, T_7 - FYM 10 t ha^{-1} + 100-60-100 N-P_2O_5-K_20 kg ha^{-1} and T_8 – FYM @ 25 t ha^{-1} .

Corm Bulking Efficiency (CBE) (%)

The corm bulking efficiency was also influenced by different fertility levels and the highest corm bulking efficiency (Table 1) was noticed in treatment T_7 (87.25%) followed by T_8 (78.87%) and T_6 (75.75%). The other treatments except T_1 experienced a moderate level of corm bulking efficiency ranging from 20.88 % (T_2) to 48.12% (T_5)..The corm bulking efficiency followed a similar trend in 3-5 MAP and 5-8 MAP retaining the superiority of T_7 to other treatments. However, treatments T_8, T_6 and T_5 were comparable with treatment T_7 and significantly differed from control. The varied nutrient regimes exerted significant positive effect on yield and yield attributes of elephant foot yam.

Corm yield (t ha^{-1})

The corm yield as influenced by different fertility management, is given in Table 2. Application of FYM @10t ha^{-1}along with N-P_2O_5-K_2O @100-60-100 kgha^{-1} increased the corm yield by 105% over the control which only recorded 18.3 t ha^{-1}. T_7 also recorded significantly more corm yield than T_4, thus justifying integrated use of FYM and fertilizer. Sole application of FYM@ 25 t ha^{-1} produced 36.1t ha^{-1} which was at par with that of T_7 (37.65 t ha^{-1}). The treatments comprising of only NPK fertilizers (T_3 and T_4) also recorded significantly more yield over control. However, the corm yield did not change appreciably at lower doses of N-P_2O_5-K_2O i.e. N-P_2O_5-K_2O @60-60-60 kg ha^{-1} (T_2). The positive responses were only obtained above the dose of N-P_2O_5-K_2O@ 60-60-60 kg ha^{-1}.The higher yield of corm might be due to inherent genetic character and positive response to the variety Gajendra to the applied manures and fertilizers. Similar to yield attributes, as fertilizer decreased the yield ha^{-1} decreased significantly. The findings of the present study are corroborative to the earlier findings of Chattopadhyay *et al.* (2006) and Saravaiya *et al.* (2010).

The highest cost of cultivation was observed with T_8 and it was followed by T_7 (Table 3). The lowest cost of cultivation was noticed in T_1 (control). The variation in cost of cultivation was due to varied level of fertilizer and manure application. The maximum gross return was observed in T_7 followed by T_8. Similar trend in net return was recorded with T_7 followed by T_6.This was due to higher yield in former case and lower cost of cultivation with moderate yield in latter case. Higher benefit cost ratio was noticed in T_7 followed by T_6. The lowest and gross and net returns as well as benefit cost ratio was observed in T_1 due to lower yield.

Literature Cited

Chattopadhyay, A., Hore, J.K., Bandopadhyay, A. and Ghosh, D. 2006. Response of varying levels of NPK fertilization on elephant foot yam grown as inter crop in Arecanut plantation. *Agric. Sci. Digest.***26** (1): 23 –26.

Das, P.K., Sen, H., Banerjee, N.C. and Panda, P.K. 1997. Biomass production and growth rate at different phenophases of elephant foot yam as influenced by chemical treatments. *Indian J. Agric. Res.***31**: 115–121.

Loomis, R.S. and Williams, W.A. 1969. Productivity and the morphology of crop stands: patterns with leaves. In:*Physiological Aspects of Crop Yield* (Ed.) Eastin, J.D., American Society of Agronomy, Madison, Wisconsin, pp. 27-47.

Mukhopadhyay, S.K.and Sen, H. 1986. Effect of nitrogen and potassium on yield and quality of elephant foot yam (*Amorphophallus campanulatus* Blume). *J. Root Crops*. **12** (2): 103-106.

Nwinyi, S.C.O. and Enwezor, W.O. 1985. Evaluation of fertilizer placement methods of white yam (*Dioscorea rotundata*). *Exp. Agric.***21**: 73-78.

Ramaswamy, N., Muthukrishan, C.R. and Suresh, M. 1982. Studies on the mineral nutrition of taro *(Colocasia esculenta* (L) Schott.).*Madras Agric. J.***69**: 135-138.

Saravaiya, S.N., Chaudhary, P.P., Patel, D.A., Patel, N.B., Ahir, M.P. and Patel, V.I. 2010. Influence of integrated nutrient management (INM) on growth and yield parameters of elephant foot yam. *Asian J. Hort*. **5**: 58-60.

Sethi, K., Mohanty, A., Naskar, S.K., Byju, G. and Mukherjee, A. 2002. Effect of sett size, spacing and NPK fertilizer on yield of *Amorphophallus* in hilly areas of Orissa. *Orissa J. Hort*. **30**: 72-75.

Stockdale, E.A., Lampkin, N.H., Hovi, M., Keating, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S., Tattersall, F.H., Wolfe, M.S. and Watson, C.A. 2001. Agronomic and environmental implications of organic farming systems. *Adv. Agron*. **70**: 261-327.

Suja, G., Susan John, K., Sreekumar, J. and Srinivas, T. 2010. Short duration cassava genotypes for crop diversification in the humid tropics: growth dynamics, biomass, yield and quality. *J.Sci. Food Agric.***90**: 188-198.

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Distribution of Different Fractions of Phosphorus in Low Land Rice Soils in Relation to Different Physico-Chemical Properties

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Abstract

Soils were collected from surface soil layer (0-15 cm) depth of rice fields of coastal zone and analyzed different fractions of phosphorus and different soil physico-chemical properties. The results show that the pH, specific conductance and organic carbon content of soils ranged from 5.28-8.46;0.001-0.0057 dSm^{-1} and 0.38 – 20.07 g kg-1 with mean values of –6.85; 0.006 dSm^{-1} and 6.83gkg^{-1} respectively. The cation exchange capacity of soils ranged from 8.4 – 36.4 cmol $_{(}$p+) kg^{-1} with a mean value of 20.78 cmol(p+) kg^{-1}. The results further reveal that the amount of Olsen P , loosely bound P, Al-P ,Fe-P, reductant soluble-P and Ca-P in soils ranged from 6.5-23.0;112.5-450.0;37.5-150.0;87.5-800; 25.0-137.5 and 250.0-1050.0 mg kg^{-1} with mean values of 12.7;239.17;101.67;507.5;49.17 and 735.0 mg kg^{-1} respectively. From the co-efficient of correlation it was found that the Olsen P content in soils showed a significant positive correlation (r= 0.60 *) with organic carbon content of soils whereas loosely bound P showed a significant positive correlation (r =0.52*) with pH of soils. Loosely bound P showed a significant negative correlation with Al-P (r = -0.84***) and Fe-P (r = -0.53*) while significant positive correlation with reductant soluble –P(r = 0.95***). The reductant soluble-P showed a significant negative correlations with Al-P (r = -0. 75***) and Fe-P (r = - 0.53*). However, cation exchange capacity of soils shows non-significant negative correlations with all fractions of P.

Key words: coastal zone, fractions of phosphorus, soil properties

Introduction

Phosphorus is one of the seventeen essential nutrients required for plant growth .It is the second most important macronutrient next to nitrogen in limiting crop growth. Plant dry weight may contain up to 0.5% phosphorus and this nutrient is involved in an array of process in plants such as in photosynthesis, respiration, in energy generation, in nucleic acid biosynthesis and as an in plants growth and metabolism, phosphorus is the least accessible macronutrient and hence most frequently deficient nutrient in most agricultural soils because of its low availability and its poor recovery from the applied fertilizers. The low availability of phosphorus is due to the fact that it readily forms insoluble complexes with cations such as aluminium and iron under acidic soil condition and with calcium and magnesium under alkaline soil conditions whereas the poor P fertilizer recovery is due to the fact that the P applied in the form of fertilizers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations. However, the distribution of available P as well as its different inorganic fractions in soils of different agro ecological regions with widespread variations in soil properties has been reportedly found with varying magnitudes affecting availability of P to plants. Keeping in view, the present investigation was undertaken to study the distribution of different fractions of P in relation to soil properties.

Materials and Methods

Fifteen soil samples were collected from the surface (0-15 cm depth) soil of the cultivated field and they were analyzed for different physico-chemical properties like pH, organic carbon, CEC, available N,P and K contents following the method described by Jackson (1973). For the P fractions, the sequential phosphorus extraction procedure, originally developed by Chang and Jackson (1957) modified by Petersen and Corey (1966) and further modified by Kuo (1996) was used. After analyzing all these data, a relationship was established between soil properties and fractions of P.

Results and Discussion

The results (Table-1) reveal that the pH , specific conductance, organic carbon content and CEC of fine aerichaplaquept and fine loamy aerichaplaquent soils varied from 5.28-8.46, 0.001-0.0057 dSm^{-1}, 0.38-20.07 gkg^{-1} and 8.4-36.4 $cmol(p+)kg^{-1}$ with mean values of 6.85, 0.006 dSm^{-1}, 6.83 gkg^{-1} and 20.78 $cmol(p+)kg^{-1}$ respectively. The highest pH in fine aerichaplaquept (Banbahadurpur) soil might be due to the greater cation exchange capacity caused by the relatively higher negative charge surfaces on to the soil colloids. As regards to the specific conductance of soils, most soils are lying in the safe zone and also suggest that both fine aerichaplaquept and fine loamy aerichaplaquent soils contain very little amount of soluble salts which does not affect most plant growth. However, average organic carbon content and CEC of soils are in the medium and optimum range which also can support plant growth optimally. With regards to different fractions of inorganic P, it was found that the amount of olsen P , loosely bound P, Al-P, Fe-P, reductant soluble P and Ca-P varied from 6.5-23.0, 112.5-450, 37.5-150, 87.5-800, 25.0- 137.5 and 250-1050.0 with mean values of 12.7, 239.17, 101.67, 507.5, 49.17 and 735.0 $mgkg^{-1}$ respectively. The highest amount of Al-P (225 $mgkg^{-1}$) and Fe-P(800 $mgkg^{-1}$)was recorded in fine aerichaplaqupet soils of Belsingha and Rukhia area respectively while that of Ca-P (1050 $mgkg^{-1}$) content was found highest in fine loamy aerichaplaquent soil of Kaipukur area. Such variation of P fractions might be due to the wide variation in soil properties like pH, organic carbon and CEC of soils.

Sihag *et al.* (2005) also confirmed the results of the present investigation who reported that the amount of different P – fractions ranged from 6.4 to 8.9 mg kg^{-1} for saloid – P, 39.8 to 49.5 mg kg^{-1} for Al-P, 60.5 to 68.4 mg kg^{-1} for Fe-P and 220.5 to 240.7 mg kg^{-1} soil of Ca-P. The amount of P recovered in saloid– P, Al-P and Ca-P forms increased significantly with the application of organic material over control. The magnitude of increase with inorganic fertilizer treatments was more in the presence than in the absence of organic material. Viswantha *et al.* (1991) reported that distribution of Al-P, rep, Reductant soluble (RS)– P, occluded – P and Ca-P did not follow a definite pattern. The Ca-P was the dominant fraction in the soil studied which also support the results of present investigation.The results of the present study also confirm the findings of Khan *et.al* (1973) who reported that the Al-P content of the soils ranged from traces to 32.5 ppm with a mean value of 12.7 ppm. The Fe-P content of the soils was always much higher than the Al-P content. It ranged from 11.25 to 111.00 ppm with a mean value of 42.10 ppm. The Ca-P was found to be the major constituent of the inorganic phosphorus in these soils. The content of this fraction ranged from 15.62 to 292.50 ppm, the average being 95.55 ppm. The content of the reductant soluble iron phosphate ranged from 7.8 to 91.4 ppm with a mean value of 24.5 ppm. This form of inorganic phosphorus was found to predominate next to Fe-P. The occluded Al-P content of the soils was very low constituting only 2.2 per cent of the total inorganic phosphorus is known to be highly resistant and is supposed not to undergo any change on water logging the soil. Sacheti *et al.* (1973) found that correlations between pH and saloid bound phosphorus were negatively significant for clayey soils, pH vs iron bound phosphorus negatively for sandy loam, sandy clay loam and clayey soils and positively for pH vs calcium bound phosphorus in the case of sandy clay loam, and clay loam soils. Calcium

TABLE 1. Physico-chemical properties and different forms of phosphorus in some soils of different blocks of South 24 parganas,West Bengal

Soil Taxonomy	Location	P^H of H_2O (1:2.5)	Specifc conductance (1 : 5) dSm^{-1}	Organic Carbon (g kg^{-1})	CEC ($cmol_c$ kg^{-1})	Olsen P (mg kg^{-1})	Loosely bound P (mg kg^{-1})	Al-P (mg kg^{-1})	Fe-P (mg kg^{-1})	Reductant soluble-P (mg kg^{-1})	Ca-P (mg kg^{-1})
Fine; Aeric Haplaquepts	Paschim Durgapur	6.54	0.0052	7.07	23.4	12	112.5	125	625	25	650
	Srirampur	7.12	0.0053	9.11	25.8	7.5	125	150	575	25	250
	Belsingha	5.47	0.0018	8.79	11.7	20	112.5	225	725	25	900
	Ramlakha	6.26	0.0049	20.07	21.1	23	175	125	400	25	500
	Rukhia	7.54	0.0046	6.69	24.5	13	137.5	125	800	25	400
	Debipur	6.53	0.029	5.36	26.9	17.5	162.5	100	175	25	825
	Bishnurampur	7.30	0.0031	3.05	15.6	13	162.5	125	700	25	950
	Harinarayanpur	6.10	0.0026	8.37	16.4	8.5	412.5	37.5	637.5	100	750
	Manika	7.26	0.001	6.85	20.8	7.5	375	37.5	562.5	75	1000
	Banbahadurpur	7.66	0.0055	0.38	36.4	6.5	450	50	250	87.5	875
	Narayanpur	8.24	0.0049	1.72	8.4	12	425	50	375	87.5	875
	Sultanpur	8.46	0.0057	3.04	18.2	10	450	50	87.5	137.5	750
Fine loamy, Aeric Haplaquents	Kismatnagar	5.37	0.0029	7.84	15.6	13	162.5	100	450	25	400
	Dhopahat	5.28	0.0015	8.41	30.5	13	162.5	100	650	25	850
	Kaipukur	7.60	0.012	5.73	16.4	14	162.5	125	600	25	1050
Range		5.28-8.46	0.001-0.0057	0.38 – 20.07	8.4 – 36.4	6.5-23.0	112.5-450.0	37.5-150.0	87.5-800	25.0-137.5	250.0-1050.0
Mean		6.85	0.006	6.83	20.78	12.7	239.17	101.67	507.5	49.17	735.0

carbonate content has provided significant positive correlations with calcium bound phosphorus in sandy loam and sandy clay loam soils. Significant correlations in case of organic carbon have been recorded for saloid bound phosphorus in sandy clay loam, reductant soluble and occluded phosphorus in sandy loam and iron bound phosphorus in sandy loam, sandy clay loam, clay loam and clayey soils.

The results (Table-2) show that the Olsen P content in soils showed a significant positive correlation (r= 0.60 *) with organic carbon content of soils whereas loosely bound P showed a significant positive correlation (r =0.52*) with pH of soils.The results further reveal that loosely bound P showed a significant negative correlation with Al-P (r = -0.84***) and Fe-P (r = -0.53*) while significant positive correlation with reductant soluble –P (r = 0.95***). The reductant soluble-P showed a significant negative correlations with Al-P (r = -0. 75***) and Fe-P (r = - 0.53*). However, cation exchange capacity of soils shows non-significant negative correlations with all fractions of P. Chandra *et al.* (1973) reported that most available fractions were saloid and aluminium phosphates, as these showed positive correlations with available phosphorus i.e., r = 0.924* and r = 0.807* respectively. Individual physico-chemical characteristics did not have any consistent effect on phosphorus availability. Organic phosphorus showed positive correlation with silt plus clay percentage (r = 0.640*) whereas it had negative correlation with pH (r = 0.570*). Organic phosphorus might be mineralized into aluminium and iron phosphates, as it had significant positive correlations, i.e., r = 0.706* and r = 0.789* respectively.

Aluminium and iron phosphates decreased with rise in pH, whereas calcium phosphate showed direct relationship with pH. The significant correlations between iron phosphate and pH and calcium phosphate and pH were r = – 0.705* and r = 0.746* respectively. Calcium phosphate was observed to have declined,

TABLE 2. Co-efficient of correlation among different soil properties

	P^H of H_2O (1:2.5)	Specifc conductance (1 : 5) dSm^{-1}	Organic Carbon (g kg^{-1})	CEC ($cmol_c$ kg^{-1})	Olsen P (mg kg^{-1})	Loosely bound P	Al-P	Fe-P	Reductant soluble-P	Ca-P
P^H of H_2O (1:2.5)	1.00	0.11	-0.55*	-0.05	-0.42	0.52*	-0.42	-0.36	0.53*	0.18
Specifc conductance (1 : 5) dSm^{-1}		1.00	-0.14	0.21	0.27	-0.16	0.01	-0.48	-0.18	0.12
Organic Carbon (g kg^{-1})			1.00	-0.02	0.60*	-0.45	0.38	0.23	-0.43	-0.45
CEC ($cmol_c$ kg^{-1})				1.00	-0.27	-0.04	-0.14	-0.18	-0.11	-0.17
Olsen P (mg kg^{-1})					1.00	-0.55*	0.60*	0.05	-0.53*	-0.02
Loosely bound P						1.00	-0.84***	-0.53*	0.95***	0.35
Al-P							1.00	0.49	-0.75***	-0.22
Fe-P								1.00	-0.53*	-0.07
Reductant soluble-P									1.00	0.26
Ca-P										1.00

trend where soils were rich in organic matter content (r = 0.568*). Iron phosphate showed negative correlation with calcium phosphate, i.e., r = – 0.661*, which might explain that calcium phosphate was converted to iron phosphate by chemical weathering.

Literature Cited

Chang, S.C. and Jackson, M.L. (1957) Fraction of soil phosphorus. Soil Science **84** :133-144

Jackson, M.L. (1973). Methods of soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Khan, S.K. and Mondal, L.N.(1973). Distribution of different inorganic forms of phosphorus in rice soils of West Bengal. *Journal of the Indian Society of Soil Science,* **21**(4) : 395-402

Kuo, S. (1996). Phosphorus. *In:* D.l. Sparks (ed.) Methods of soil analysis: Chemical Methods. *Part 3.SSSA No. 5. ASA-CSSA-SSSA, Madison, WI*. PP. 869-919

Petersen, G.W. and Corey, R.B. (1966) A modified Chang and Jackson procedure for routine fraction of inorganic soil phosphates. *Soil Science Society of America Proceedings* **30**, 563-565

Sacheti, A.K. and Saxena, S.N. (1973). Relationship between some soil characteristics and various inorganic phosphatic fractions of soils of Rajasthan. *Journal of the Indian Society of Soil Science,* **21**(2) : 143-148

Sihag, D., Singh, J.P., Mehla, D.S. and Bhardwaj, K.K. (2005). Effect of integrated use of inorganic fertilizers and organic materials on the distribution of different forms of nitrogen and phosphorus in soil., *Journal of the Indian Society of Soil Science, **53**(1) : 80-84*

Viswanatha, J. and Doddamani, V.S. (1991). Distribution of phosphorus fractions in some vertisols., *Journal of the Indian Society of Soil Science,* **39** : 441-445

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Soil Surface Charge is a Function of Soil Chemical Constituents

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Abstract

A laboratory study was conducted to find out the charge characteristics of soils of sub-tropics using net charge and pristine point of zero charge determined by ion adsorption method. The ΔpH value was presented as a measure of pedogenic development. The decrease in ΔpH value was interpreted as indicating that the soils are approaching a steady- state with time. Results of the study revealed that the soil formed under sub-tropical conditions had a high surface charge attributed to the higher amounts of iron and aluminium oxides. Variability in the magnitude of this surface charge was attributed to the effect of organic functional groups or contribution from iron or aluminium block exchange sites. The results show that zero point charge varies with soil according to the variations of organic carbon and sesquioxide contents. Surface charge was intimately related with organic carbon, clay content, amount of iron and aluminium oxides and chemical composition.

Key words: clay, iron and aluminium oxides, surface charge

Introduction

The processes of soil genesis operate at the boundary between the soil particles and soil solution. Initially the soil solution may be in direct contact with the crystalline surface of the soil mineral grains; with time, the most easily soluble minerals weather through processes such as solution, oxidation, and hydrolysis. The result is that the surface is contact with the soil solution changes with time from one composed of crystalline minerals to one compound of the alteration products of soil weathering. Studying soil genesis has used different approaches to study the chemistry of non-crystalline material making up the surfaces of the soil particles.

One of the possible alternative approaches to the study of amorphous coatings on soil particles is to study the exchange reactions which take place at the interface between the soil particles and soil solution. This can be done using the potentiometric titration technique, which utilizes the adsorption and desorption of H^+ and OH^- ions to measure the surface charge characteristics. Specifically the titration curves at different ionic strengths cross at a common point, thus determining the zero point of charge, and providing a measure of the permanent or pH –dependent exchange capacity.

This technique has been applied to soils of tropical regions (Gallez *et al.*, 1976), and to areas of soils developed on volcanic ash (Epinosa *et al.*, 1975), to soils of temperate regions (Laverdiere *et al.*, 1977).

The natural charge of soil particles is divided into permanent charge and variable charge components (Uehara and Gillman, 1981). A given soil may be dominated by either permanent charge or variable charge or their mixture, depending on the degree of its weathering and type on mineral constituents (Sparks, 2002; Chorover *et al.*, 2004; Sposito, 2008). The objectives of this research, therefore, were to determine the charge characteristics of some tropical soils of India.

Materials and Methods

Sampling sites

Three soil samples were collected from Falta, Laxmikantapur of South 24 parganas and Lalghar, of West Medinipur district of West Bengal, India. The soils are mostly tropical climate with an annual rainfall of approximately 1250mm and mean temperature of approximately 24.8^{0}C (Metrological department, 2017).

The sampling sites and classification of the soils in this study are given in Table 1. The soil samples are air dried, crushed, and then passed through 2mm sieve for laboratory analysis.

Physico-chemical properties

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). Cation exchange capacity was determined by NH_4OAC at pH 7.0 and is defined by the some of the exchangeable cations that a soil can absorb (Chapman., 1965). Anion exchange capacity is determined by colorimetric methods (Frank E. Clarke, 1949). Particle size distribution was analysed by the pipette method (Gee and Bauder., 1986). The ΔpH index was calculated from the difference between pH_{kcl} and pH_{water} (Mekaru and Uehar, 1972). Exchangble Al (Bertsch and Bloom, 1996) and exchangble Fe Sparks (1996). The Fe and Al contents associated with secondary minerals were determined in extracts obtained after boiling both 1g of soil for 30minutes in 20ml 9(M) H_2SO_4. The acid extract were analysed for Al and Fe. Soil fused with alkali and total Fe and Al estimated by atomic absorption spectrometry (AAS) (Sparks, 1996).

Surface charge analysis

Ion adsorption method

An estimate of the CEC and AEC as a function of pH was determined by measuring the amount of K^+ and Cl^- retained by the soils at different pH using a modification of Schofields method (Schofield, 1949). Based upon the unknown mineralogy of these soils, it was assumed that the clays contained essentially no sites capable of specifically absorbing K+; and therefore that KCl could be treated as an indifferent electrolyte. Triplicate 2g samples of soil were weighed in centrifuge tubes and washed with 0.1 (M) KCl to minimize soluble Al; after discarding the supernatants, 20ml of the same solution were added and the pH adjusted with KOH or HCl to give a pH range between 2 and 8. The samples were equilibrated at room temperature (24+/-2□C) by shaking intermittently on a reciprocal shaker for 12 hr. Then the samples were centrifuged, the supernatants discarded, and 20ml 0.01 (M)KCl added; this (0.01) M KCl wash was repeated two more times. After the final washing, the supernatant pH was measured as well as the Cl^-, K^+ and Al concentrations. Next, the adsorbed K^+ and Cl^- ions were displaced by washing the soil with 0.5 (M) NH_4NO_3. The amounts of K^+ and Cl^- displaced, after correction for the entrained KCl with in the soil volume, were used as estimates of the negative and positive charges, respectively. Chloride was measured using a specific ion electrode with a double junction reference electrode filled with 100gKg^{-1} KNO_3 solution in the outer chamber, and K^+ by flame photometer.

Statistical analysis

Each experiment was treated as a completely randomized design. Because the experiments were performed individually on each soil, comparisons of surface charge of the soils as a function of pH were accomplished by the use of correlation coefficient, were used to determine statistical significance of any differences in the surface charge measurements.

Results and Discussion

Important soil chemical and physical properties of the soil used in this study are given in Table 2. Where it can be seen that Lalghar soils are more acidic (5.25) compare to Falta and Laxmikantapur soil. Falta and Laxmikantapur soil are poor in organic carbon than Lalghar soil. All these experimental soils had ΔpH less than zero, which indicate they present negative net surface charge (Meakru and Uehara, 1972).

Clay content in the Larghar soil was significantly higher than Falta and Laxmikantapur, and this is reflected in the corresponding CEC values of these soils with relatively higher CEC of Lalghar soil

TABLE 1. Sampling site, Soil order, Vegetation Type and texture

Sl.No.	Location	Soil order	Vegetation type	Texture
1.	Falta soil, West Bengal, India 22^0 35´N, 88^0 44´E	Fluvaquent	Rice-rice-rice	39%silt, 26%clay, 35%sand
2.	Laxmikantapur soil, West Bengal, India 26.32^0 N, 89.45^0 E	Endoaquepts	Rice-rice-rice	35%silt, 25%clay, 40%sand.
3.	Lalghar soil, West Bengal, India 22.58^0N, 87.04^0E	Haplustalfs	Tropical forest	26%silt, 36%clay, 38%sand.

than Laxmikantapur and Falta, indicated the dominance of Kaolinite mineral in the clay fraction of these soils. Percent of organic matter increases from Falta to Lalghar soil.

Despite greater percentage of organic matter in the Lalghar soil as compare to Falta (1.38%) and Laxmikantapur (1.42%) soil, which tends to lower the point of zero charge (Van Raij and Peech, 1972), the PZC of Lalghar (3.35) was lower than Falta (6.05) and Laxmikantapur (5.70). With increasing percent of organic matter and clay content zero point charge reduces. The magnitudes of changes in the Lalghar soil are higher than those of Falta and Laxmikantapur soil because of the presence of organic matter and dissociation of organic matter functional groups. Organic matter is an important source of CEC in these soils (Carvalho *et al.*, 2009). With increasing percent of organic matter net charge increases that increament is very high even in small increament of organic matter. Cation exchange capacity of Lalghar soil is higher than the Falta and Laxmikantapur soil probably an effect of organic matter content (Morais *et al.*, 1976). Charge character increases with increasing salt concentration. In this study it appears that organic matter has a depressing effect on ZPC (Gallez *et al.*, 1976). The evidence presented is based on comparison of the surface charge characteristics of samples which contain different amounts of organic matter, but which are almost similar in other respects. In the present experiment, three soils with a broad range surface charge properties are estimated, this is due to different amount of organic matter, iron and aluminium oxide and salt concentrations. In all the samples, pH in water was greater than that measured in KCl, indicating that the ZPC of the untreated samples was located below the zero point titration (ZPT). Total concentrations of iron and aluminium oxide are high in Lalghar soil compare to Falta and Laxmikantapur, provide positive surface charge in the soil. Net charge of the soil is estimated by substracting the CEC value at a give pH from the corresponding AEC value, these values are shown in Table2 with the calculated net charge values. Lalghar soil possesses higher net charge than Falta and Laxmikantapur soil. This has been attributed to the negative charge arising from the greater organic matter content. Presence of dissociated organic functional groups and unblocked exchange sites of clay and amount of iron and aluminium oxide.

Literature Cited

Bertsch, P.M., Bloom, P.R., 1996. Aluminum. In sparks, D.L.(ed.) Methods of Soil Analysis. Part.3. Chemical Methods. American society of Agronomy and Soil Science Society of America, Madison. 3: 517-550.

Carvalho, J.L.N., Cerri, C.E.P., Feigl, B.J., Piccolo, M.C., Godinho, V.P., Cerri, C.C. 2009. Cerbon sequestration in agricultural soils in the cerrado region of the Brazilian Amazon. Soil Tillage Research. Amsterdam. 103: 342-349.

Chapman, H. D., 1965. Cation exchange capacity. In Methods of Soil Analysis (Edited by Black, C. A.). Number 9 in the series Agronomy: Am. Inst. Agronomy, Madison, Wisconsin. 2: 891-901.

Table 2. Chemical and Physical characteristics of soils.

Soil Sample	pH_{water}	pH in 1(N) KCl	ΔpH^*	EC mSm^{-1}	%O. C	%O.M	EX. Fe g/Kg	Ex. Al g/Kg	Total Feg/Kg	Fe_2O_3 g/Kg	Total Al g/Kg	Al_2O_3 g/Kg	%sand, silt, clay	ΔpH
Falta	6.35	6.20	-0.15	0.08	1.38	2.40	0.28	0.12	22.6	32.3	16.2	30.6	35, 39, 26	=
Laxmikantapur	6.10	5.90	-0.20	0.06	1.42	2.47	0.32	0.16	32.5	46.4	21.8	41.1	40, 35, 25	pH_{KCl}
Lalghar	5.25	4.30	-0.95	0.01	1.85	3.22	0.50	0.20	58.5	83.6	15.5	29.2	38, 26, 36	pH_{water}

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

Chorover, J., Amistadi, M., Chadwick, O.A., 2004. Surface charge evolution of mineral-organic complexes during pedogenesis in Hawaiian basalt Geochim. Cosmochim. Acta, 68:4859–4876.

Espinoza, W., Gast, R.G., Adams, R.S., Jr 1975. Charge characteristics and nitrate retention by two Andepts from southern chile. Soil Science Society of America Proceding. 39: 842-846.

Frank, E. Clarke. 1949. Improved Colorimetric and Titrimetric Methods; Chemical Enginnering Laboratory, U.S. Naval Engineering Experiment Station, Anapolis, Md.

Gallez, A.,Juo, A.S.R., Herbillon, A.J., 1976. Surface and charge charactenstics of selected soils in the tropics. Soil Science Society of America Proceding. 40:601-608.

Gee, G.W., Bauder, J.W., 1986. Particle Size Analysis. In : Methods of Analysis; Part 1, Physical and Mineralogical methods, 2[nd] edn. (ed.A.Klute), American Society of Agronomy, Madison, W.I. 2:383-411.

Indian Metrological department. Goverment of India, Regional Metrological Centre, Kolkata

Laverdiere, M.R., Weaver, R.M 1977. Charge characteristics of spodic horizon. Soil Sci. Soc. Am. J. 41: 505-510.

Meraku, T., Uchara, G., 1972. Anion adsorption in Ferruginous tropical soils. Soil Science Society of America Proceeding. 36: 296-300.

Morais, F.I., Page, A.L., Lund, L.J., 1976. The effect of pH, salt concentration, and nature of electrolytes on the charge characteristics of Brazilian tropical soils. Soil Science Society of America Journal. 40:521– 527.

National Soil Survey Center. 1996. Soil Survey Laboratory Methods Manual. U.S. Department of Agriculture, National Soil Survey Center., Soil Survey Laboratory., Soil Survey Investigation No. 42. Version 1.

Nelson, D.W., Sommers, L.E., 1996. Total carbon and soil organic matter. In Methods of Soil Analysis. Part III.Chemical Methods. D.L. Sparks, A.L.Page, P.A. Helmke, and R.H. Loeppert (eds.) American Society of Agronomy, Inc, Madison, Wi, 3:961-1010.

Schofield, R.K., 1949. Effect of pH on electric charges carried by clay particles. Journal of Soil Science. 1: 1-8.

TABLE 3. PZC, CEC, AEC, Net charge and their relation with various chemical characters.

Soil Sample	*PZC	AEC ($Cmol_c$ Kg^{-1})	CEC ($Cmol_c$ Kg^{-1})	Net Charge ($Cmol_c$ Kg^{-1})	Correlation between PZC & pH	Correlation between soil OC & PZC	Correlation between net charge & OC	Regression value (clay & OC) (r*<0.05)
Falta	6.05	24.5	26.8	2.3				
Laxmi-kantapur	5.70	20.0	22.5	2.5	0.995099	-0.99909	0.998827	0.9873
Lalghar	3.35	28.0	36.5	8.5				

*point of zero charge (PZC= $2pH_{KCl}-pH_{water}$), AEC= Anion Exchange Capacity, CEC= Cation Exchange Capacity.

Sparks, D.L. 1996 (Ed.) Method of Soil Analysis. Part 3. Chemical Methods. American Society of Agronomy and Soil Science Society of America, Madison, WI.

Sparks, D.L., 2002. Environmental Soil Chemistry, 2nd ed. Academic Press, San Diego. CA.

Sposito, G., 2008. The Chemistry of Soils. Oxford University Press, New York. 2:330.

Uehara, G., Gillman, G.P. 1981. The Mineralogy, Chemistry and Physics of Tropical Soils with Variable Charge Clays. West View Press, Boulder, 145.

Van Raij, B., Peech, M., 1972. Electrochemical properties of some oxisols and alfisols of the tropics. Soil Science Society of America Procedings. 36:587-593.

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Physico Chemical Analysis of Bael (*Aegle Marmelos*) Fruit Pulp, Seed and Pericarp

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Abstract

India is the botanical garden of the world as it is the largest producer of medicinal herbs. Bael (*Aegle marmelos*) has been known to be one of the most important medicinal plants of India since Charak (1500 B.C) Bael (*Aegle marmelos*) also known as Bengal quince or golden apple is medium sized, deciduous tree belonging to family Rutaceae. All the parts of this tree including stem, bark,root, leaves and fruit at all stages of maturity have medical properties and have been used in the traditional medicine for a long time. The ripe fruit is of considerable medical value when it just begins to ripen. The ripe fruit is aromatic, astringent, cooling and laxative. The unripe or half ripe fruit is stomachic, anti-scorbutic, and digestive . Ripe bael fruit is regarded as best of all laxatives.

Keywords: aromatic, bael, digestive and laxative, traditional medicine

Introduction

India has a large variety of flora and fauna which is available from temperate to cold deserts to sub-tropical and tropical climates and regions. References of such wild varieties of herbs and shrubs with rich medicinal values us available in our epics. 'Rigveda' one of the oldest repositories of human knowledge mention use of 67 medicinal plants. 'Yajurveda' and 'Atharveda' also mentions use of many plants for therapeutic purpose. Ayurveda and Unani type of treatments with healing touch have therapeutic and nutritional value of medicinal plants but unfortunately,the knowledge and information had not been preserved for posterity.

Bael (*Aegle marmelos*) is one of the medicinal plants of india. It is also known as golden apple or Bengal quince .It is a medium sized deciduous tree belonging to family Rutaceae. Other names of bael include maredu, bill, bill patra, balwa, vllwam and kuvalam in India. Bael is native of northern India, but is found widely throughout the Indian peninsula and in Ceylon, Burma, Thailand and Indo-China. The bael tree is Indigenous to India and the history of this tree has been made in 'Yajurveda' In early Buddhist and jain literature (8000-325 B.C), methods of ripening this fruit have been described. Bael fruit has also been portrayed in paintings of Ajanta caves . It grows wild throughout the low hills of Himachal Pradesh, ascending upto 1000 meters. It is found in plenty in wild forms in the states of Uttar Pradesh, Orissa, West Bengal, and Madhya Pradesh. However, the fruits of the wild trees are considerably smaller than those of the cultivated types grown in the plains.

The fruits are good to taste containing 40 per cent TSS. The bael tree is one of the most useful medicinal plants of India. Its medicinal properties have been described in the ancient medical treatise in Sanskrit, "Charaka Samhita". All the parts of this tree including stem, bark,root, leaves and fruit at all stages of maturity have medical virtues and have been used in the indigenous medicine for a long time. The ripe fruit is of considerable medical value when it just begins to ripen. The ripe fruit is aromatic, astringent, cooling and laxative. The unripe or half ripe fruit is stomachic, anti-scorbutic, and digestive. Ripe bael fruit is regarded as best of all laxatives. (K.P. Sampath kumar 2012) It cleans and tones up the intestines. Its regular use for two or three months can throw out even the old accumulated faecal matter. The pulp of the ripe fruit can also be taken with a spoon without the addition of milk or sugar. About 60 g of fruit will suffice for an adult.(Krushna *et al* 2009).

The unripe or half ripe fruit is perhaps, the most effective food remedy for chronic diarrhea and dysentery. Dried bael or its powder provides the better results.. The bael fruit when it is still green, is sliced and dried in the sun. These slices can also be reduced into powder and preserved in airtight bottles. An infusion of bael leaves is regarded as an effective food remedy for peptic ulcer. The beal fruit taken in the form of beverage has also great healing properties because of its mucilage content. This substance forms a coating on the stomach mucosa and thus helps in healing of ulcers (Sampath *et al* 2012).

Materials and Methods

Procurement of Raw Material

The bael fruits were procured from local market of Ludhiana In Punjab, ensure the proper maturity of the fruits, March harvest fruits were used in the study. Fruits were broken and pulp was taken out and dried in the air drier. Similarly, seeds and pericarp were dried for physical, chemical and pharmacological analysis.

Physical Properties of Bael Fruit

All linear measurements were taken by using vernier caliper. Other quality attributes like colour, appearance, shape, uniformity and defects were recorded visually. Weights of the samples were taken by using the physical balance.

Volume

For measuring the volume, the fruits were put in a measuring cylinder. The water was poured in this measuring cylinder upto the mark (A ml). After a few minutes, when there were no air bubbles inside, the water was drained in another measuring cylinder and noted the volume of water (B ml). Volume displaced by fruits = (A -B) ml

Specific gravity

The specific gravity of the fruits was calculated by applying the formula as given below:

$$\textbf{Specific gravity (g/cc)} = \frac{\text{weight of fruits}}{\text{Volume of water displaced}}$$

Chemical Properties of Bael Fruit

For analyzing chemical properties of the fruit, the pulp, seed and pericarp of fruit were separated, dried in the air drier and ground. Moisture, titrable acidity, sugars, crude fibre, crude fat, crude protein and ash content were estimated by employing the standard methods of analysis (AOAC, 2000).

pH was measured by control dynamic digital Ph meter.

Minerals were analysed by acid digestion (Piper 1950)

Iron in the digested sample was determined by atomic absorption spectrophotometer according to method of Lindsey and Norwell (1969). Other minerals including calcium, magnesium, phosphorus, zinc and potassium etc. were determined by the flame photometer according to the method of Lindsey and Norwell (1969).

Pharmacological Properties of Baal Fruit: For pharmacological analysis. dried and ground samples were used.

Anti - nutritional factors: Tannins were estimated by determining their oxidisability by potassium permanganate solution by standard method of AOAC (2000). While oxalic acid was determined by method given by Italia 2002.

Ascorbic acid (AOAC, 2000): The principle for determination of ascorbic acid content is based on the reduction of 2.6 - dichlorophenoi indophenol by ascorbic acid.

Results and Discussion

Physical Characteristics of Bael

Assessment of physical characteristics of a fruit is very important for quality evaluation of fruits. The external colour of the fruit was brownish yellow and the fruit shape was roundish-oblong. The polar and transverse diameter of bael was found to be 12.965 and 13.35 cm respectively. The pulp had a bright yellow colour. As per the earlier reports (Singh and Ali, 1992) the colour of pulp was found to be yellow at maturity. Jauhari *et al*. (1969) observed the colour to be brownish yellow, yellowish green and greenish yellow in different varieties of bael. Prasad and Singh (2001) reported the polar and transverse diameter within a range of 14.20 to 8.97 cm and 13.80 to 17.80 cm for different varieties of bael, which supports the present findings. Singh *et al*. (2000) reported the values for fruit length and diameter between 39.87 to 53.27 cm and 37.37 to 54.53 cm, respectively.

Fruit weight varies between green and ripe stage of maturity. The average weight of ten fruits was noted to be 1120 g. The value for same parameter was recorded to range between 1063 to 2950 g by Prasad and Singh (2001) while Kaushik *et al* (2000) reported the results to be around 650 to 764 g. The variations in fruit weight could be due to varietal or agro climatic conditions.

The specific gravity of the fruit was found to be 1.11 g/cc. Singh *et al* (2000) reported specific gravity to vary between 0.81 to 1. 06 g/cc thus, supporting the results of present investigation. According to Roy and Singh (1980), the increase in specific gravity was mainly due to increase in dry matter content of fruit However, the fall in specific gravity during after harvest was mainly due to loss in weight without corresponding decrease in volume.

The volume of fruit was recorded to be 1. 01 litre. Singh *et al* (2000) also reported the volume of the fruit to be 0.81 to 2.19 litres.

The data in Table 1 depicts the per cent peel value of bael fruit to be 24 while edible portion i.e., pulp to be 68 per cent. The pulp and peel per cent as reported by Singh *et al* (2000) were 38 .19 - 56.17 and 16. 28 – 21. 13 per cent, respectively which were near to the investigated values. Kumar *et al* (1996) gave a pulp percentage of 71. 70 per cent.

Seeds were compressed, oblong. white having cotton like hair on their outer surface and comprises about 1.3 per cent of fruit weight. Fruits were fully ripe, free of bruises. blemishes and uniform in size. The fruits used were free from any defects.

Chemical Characteristics of Bael

Moisture

Moisture content is an index of stability and quality and a measure of yield and quantity of food solids. A perusal of data given in Table 2 illustrates that moisture content of bael fruit pulp, seed and pericarp is 61.06, 31. 80 and 38.92 per cent, thus indicating the high perishability of fruit. The moisture content of the pulp gradually decreased with the increase in dry matter content. A very close value of 61.50 per cent was reported by Roy *et al* (.2001) and Gopalan of al (2000). Similar results were reported by Subbian *et al*. (2000) i.e, 61.50 per cent.

pH

It is a measure of active acidity which inferences the flavour or palatability of a fruit or a product and effects the processing requirements The pH was measured with digital pH meter buffered with 4.0 and 7.0 and the values wore recorded to be 4 .95,5.49 and 5.28 for pulp, seed and perfume. respectively (Table 2). Roy *et al* (1972) recorded a pH range of 5.00 to 5 30 in bael fruit pulp. The results reported by Teaotia *et al* (1963) also gave a pH range of 4.70 to 5.00 in pulp of the fruit .

Acidity :The acid content of foods directly affects their flavour. The acids present are largely responsible for the tart or sour flavour. Total acidity determination is useful as a measure of this tartness, The acidity measured by titration method as per cent citric acid was 0.3 per cent in bael fruit pulp, while in seed and pericarp it was found to be 00 06 and 0.29 per cent, respectively (Table 2) Kaushik *et al*. (2000) recorded

Table 1. Physical parameters of bael fruit

Parameter	Value
External Colour	Brownish yellow
Pulp Colour	Bright yellow
weight(g)	1120
Polar Diameter (cm)	12.96
Transverse Diameter (cm)	13.35
Specific Gravity (g/cc)	1.11
Volume (I)	1.01
Peel(%)	24
Pulp(%)	68
Seed(%)	1.3
Shape	Roundish-oblong

Table 2. Chemical constituents of bael fruit.

Parameter	Pulp	Seed	Pericarp
Moisture (%)	61.06	31.80	38.92
PH	4.95	5.49	5.28
Acidity(% Citric acid)	0.30	0.06	0.29
Crude Protein(%)	3.64	1.01	1.31
Ash(%)	2.85	4.02	3.18
Crude Fibre(%)	4.80	—	30.65
Crude Fat(%)	0.43	1.08	0.06
TSS Brix	36	—	—

0 .50 per cent acidity in bael fruit while Singh *et al* (2000) reported an acidity range of 0.49 to 0.88 per cent The acidity decreases during fruit development and ripening and it could be due to rapid utilization of organic acids and conversion of organic acids into their salts and sugars.

Crude protein

Data with respect to protein content isdepicted in Table 2. The protein content of bael fruit pulp, seed and pericarp was found as 3. 64. 1.01, and 1.31 per cent, respectively in the present study and is found in consonance with the range reported by various researchers. The protein content of bael fruit was reported as 1.80 per cent by Roy *et al.* (2001) while Kaushlk *et al.* (2000) gave a value of 3.30 per cent.

Gopalan of al. (2000) reported the value for crude protein to be 1.80 which is same as given by Roy of at (2001). Crude protein content fall progressively during fruit development but there was a slight increase at ripening. Direct relationship of crude protein content with the respiration rate was thus reported.

Ash

The ash content was reported to be 2.85, 4.02 and 3.18 per cent in bael fruit pulp, seed and pericarp, respectively (Table 2). An ash content of 1.7 mg per 100 g was reported by Roy *et al.* (2001) and Gopalan *et al.* (2000). However, a higher value for ash content was recorded by Parmar and Kaushal (1982) i.e., 2.66 per cent.

Crude fibre

The value reported by Roy of al. (2001) for crude fibre content of bael fruit was quite low (0.31 per cent) as compared to present study. However, the present values were in consonance with the values reported by Kaushik *et al.* (2000) i.e., crude fibre content of bael fruit was reported to be 4.5 per cent. Gopalan *et al.* (2000) reported the value to be 2.90 per cent.

Crude fat

The crude fat content for bael fruit pulp was found to be 0.43 per cent, which is close to the values reported by Gopalan *et al.* (2000).

Minerals

The values for various minerals found in bael fruit pulp as P, K,Ca, Mg, Fe, Cu and Zn were 51.6, 603, 78, 4.0. 0.55. 0.19, 0.28 mg per 100g respectively (Table 3). These values are well in agreement with the results reported by Gopalan *et al* (2000). For seed and pericarp, the values for P, K, Ca, Mg, Fe, Cu and Zn were recorded as 3.3 and 2.8,108 and 210, 0.0 and 6, 0.82 and 0.91, 0.08 and 0.02, 0.01 and 0.0. 0.03 and 0.02 respectively.

Sugars

According to the table 4, the non-reducing and total sugars content of bael fruit pulp are 9.93 and 14.35 per cent respectively. Prasad and Singh (2001) reported the results for non-reducing sugars in a range of 11.52 to 14.93 per cent which is close to the value obtained in the present investigation. A value of 2.04 per cent for non-reducing sugars was given by Parmar and Kaushal (1982) The total sugar content of 8.36 per cent was reported by Parmar and Kaushal (1982),while the results reported by Roy *et al*. (1972) gave a much higher value for total sugars i.e, in a range of 12.5 to 16.7 per cent which are well in accordance with the results of present investigation. The reducing, non-reducing and total sugar content for pericarp were found to be 0.92, 0.91 and 1.83 per cent, respectively (Table 4)

Reducing sugars

The reducing sugar content was found to be 4.42 per cent and 0.92 per cent in bael fruit pulp and pericarp, respectively (Table 4). Reducing sugars constitute about 60 to 70 per cent of total sugars present in bael (Teaotia *et al*. 1963) i.e., 12.31 to 17.97 per cent. Prasad and Singh (2001) reported 3.43 to 4.59 per cent reducing sugars in bael which is in consonance with the present study. Reducing sugar content of 6.21 per cent was reported by Parmar and Kaushal (1982), while Jauhari *et al*. (1969) reported the value to range between 2.7 and 5.2 per cent which is again in accordance with the present findings.

Pharmacological Characteristics of Bael

Anti-nutritional factors

Many foods particularly those of plant origin contain a wide range of anti-nutritional factors which interfere with the assimilation of nutrients contained in them.

Tannins and oxalates

Tannins are condensed polyphenolic compounds which are widely distributed in plant kingdom. The tannic acid content in bael fruit is expressed as per cent gallotannic acid. As is evident from Table 5, the bael fruit pulp contained 0.42 per cent of tannic acid and 1.03 per cent in pericarp. The results reported by Kaushik *et al.* (2000) gave a value of 6.6 mg/100 g for tannins. The tannin content of 0.21 per cent was given by Parmar and Kaushal (1982) which is lower than the value reported in the present investigation However, Roy and Singh (1978) reported Phenolics as tannic acid in bael fruit to be in a

Table 3. Mineral constituents of bael (mg per 100 g)

Mineral	Pulp	Seed	Pericarp
Phosphorus	51.60	3.30	2.80
Potassium	603.00	108.00	210.00
Calcium	78.00	—	6.00
Magnesium	4.00	0.82	0.91
Iron	0.55	0.08	0.02
Copper	0.19	0.01	—
Zinc	0.28	0.03	0.02

Table 4. Sugar conent in bael (percent)

Sugar	Pulp	Seed	Pericarp
Reducing Sugars	4.42	—	0.92
Non-reducing Sugar	9.93	—	0.91
Total Sugars	14.35	—	1.83

Table 5. Antinutritional content in bael

Consitituent	Pulp	Seed	Pericarp
Tannic Acid gallotannic acid)	0.42	—	1.03
Oxalates (g/100g)	0.96	0.20	0.30

Table 6. Ascorbic acid content in bael

	Ascorbic acid (mg/100g)
Pulp	22.50
Seed	2.80
Pericarp	8.00

range of 1755 to 3000 mg per 100 g Total phenols and tannins were significantly lower at ripe stage as compared to green stage of maturity. The reduction in tannins began with the increase in sugar synthesis and the original acrid taste of fruit diminishes. Oxalic acid, a dicarboxylic acid or its salts are widely distributed in plant foods. Oxalic content in bael fruit pulp, seed and pericarp was found to be 0.96, 0.20 and 0.30 g per 100 g, respectively as shown in Table 5.

Ascorbic acid

The perusal of Table 6 depicts that ascorbic acid content of bael fruit pulp, seed and pericarp was 22.5, 2.8 and 8.0 g per 100 g,respectively. Ascorbic and content in a range of 7.82 to 17. 63 mg per 100 g was reported by Prasad and Singh (2001). A value near to it i.e., 18.3 mg per 100 g was recorded by Kaushik *et al* (2000) in ripe stage of bael and a value of 11 .7 mg per 100 g in green stage of beet fruit.

Conclusion: The present study was an attempt to analyse the different properties of bael fruit pulp, seed and periarp to find out the future perspectives of this fruit. The edible pulp, 100g of bael fruit contains 61.06g water, 3.64 g crude protein, 0.43 g fat, 2.85g ash, 603 mg potassioum, 78 mg calcium, and 51.60 mg phosphorous with a total sugar content of 14.35 percent. Ascorbic acid content of 22.50m The TSS content of about 36 make it suitable for development of various products. Ascorbic acid content of 22.5mg/ 100g fruit pulp makes it a good choice to be used as a source of vitamin c.

Literature Cited

Anonymous., 2000, Official methods of analysis of the association of official analytical chemists, 17th edition AOAC, Washington. DC.

Gopalan, C., Ramasastri, B.V. and Balasubramanian, 2000. Nutritive value of Indian foods.National institute of nutrition, ICMR, Hyderabad.

Jauhari OS, Singh RD, Awasthi RK. 1969,Survey of some important varieties of bael (*Aeglemormelos* Correa.). *Punjab Hort J*, **9:**48-53.

Jauhari OS,Singh RD, 1971, Bael a valuable fruit. *Indian Hort.,* **16**(1): 9-10.

Kaushik, R.A., Yamdagni, R. and Dhawan, S.S., 2000, Physico-chemical charecteristics of *Bael* fruit at green and ripe stage of maturity, *Haryana Jl of Horticultural Sciences,* **29 (1&2)**:44 45.

Krushna, G., Kareem, M.A. and Devi, K.L.,2009, Antidyslipidaemic effect of *Aegle marmelos Linn.* fruit on isoproterenol induced myocardial injury in rats, International Journal of Pharmacology, **6**:2.

K.P.Sampath kumar, M.Umadevi, Debjit Bhowmik, Durgesh Mohan Singh, A.S. Dutta, 2012, Recent Trends in Medicinal Uses and Health Benefits of Indian Traditional Herbs *Aegle Marmelos*. The Pharma Innovation*,* **1**(4): 57-65.

Kumar, D., Rajput, C.B.S. Singh, S.P. and Kumar, D., 1996, Survey of some important bael (*Aegle marmelos*) genotypes in Varansi region. Recent Horticulture, 3(1):49-51.

Lindsey, W..L. and Norwell, M.A.,1969, A new DPTA-TEA soil test for zinc and Iron. Agronomy abstract 61-84.

Parmar, C. and Kaushal, M.K.1982, Wild fruits of the sub-Himalayan region. *Kalyani Publishers*, New Delhi, India, **1**:1-5.

Piper, C.S., 1950, Soil and plant analysis, Inter science Publication, New York.pp:212

Prasad, Yogesh and Singh, R.P., 2001, Evaluation of bael (*Aegle marmelos*) in Uttar Pradesh and Bihar areas. Haryana Journal of Horticultural Sciences. 30 (1&2): 70-71.

Roy, S.K., Pande, R.M., and Singh, R.N., 1972, Preliminary studies on availability of ripe *Bael* fruit in off season. *Indian J of Horticulture,* **29**: 344-347.

Roy, S.K. and Singh, R.N., 1980, Studies on changes during development and ripening of *Bael* fruit, *Punjab Horticulture Journal,* **20**(3): 190-197.

Roy, Deepti, Mishr, K.K., and Mishr, N., 2001, Labhkari Bael.Phal Phool, pp 26-27.

Singh Rajesh, Misra KK and Jaiswal HR. 2000. Studies on physico-chemical characters of fruits of bael genotypes. *Indian J of Horticultural* 57(4):314-317

Subbian,P., Annadurai, K., and Palaniappan, S.P., 2000, Nutrition,agricultutral facts and figures. Kalyani publishers, **1**:223.

Teaotia, S.S., Mauraya,V.N. and Agnihotri,B.N., 1963, Some promising varieties of Bael (aegle marmelos correa) of eastern districts of Uttar Pradesh. *Indian J of Horticulture*, **20** (3&4):210-214.

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Fibre Yield Heterosis in *Tossa* Jute (*Corchorus Olitorius* L) Across Environments

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Abstract

Five experimental hybrids of tossa jute were evaluated for fibre yield and standard heterosis over locations and years. Seeds of all five hybrids were produced by hand emasculation and hand pollination. Five hybrids and three inbred checks were grown in RBD over six locations and three years. Locations selected, are in the main *tossa* jute belt dispersed across two subdivisions of North 24 Paraganas district of West Bengal. Variance analysis suggests that inclusion of locations and years is equally important for such studies. Significant yield difference is observed between checks and hybrids. Expression of yield heterosis of three hybrids, Russian Green × JRO 620, Russian Green × Sallyout and JRO 632 × Russian 1, fluctuated both in negative and positive directions between locations and years while yield and heterosis level of best two hybrids; namely, Tanganyika1× O50-4963 and Tanganyika1 × Russian Green, although varied between locations and years, are still relatively consistent. Results suggest that negative influence of environments limits expression of potential heterosis. Mean fibre yield of above best two hybrids is 35.7 and 36.3 q ha^{-1} respectively. And these two hybrids are significantly superior to rest three and the latter is superior to the former. Overall mean significant high heterosis for Tanganyika1×O50-5963 against the standard check, JRO 524 is 11.3 % and that for Tanganyika1× Russian Green is 16.5 %. The former hybrid appears more tolerant to the "unspecified abiotic stress" in lower yielding sites while the latter is responsive in favourable growing conditions. Heterosis breeding in tossa jute appears promising. Population improvement scheme has been suggested for increasing heterosis level further.

Introduction

After cotton, jute is the second important natural fibre crop. India ranks first in jute production followed by Bangladesh. Other jute producing countries lag much behind the former two countries in terms of area and production. India earns foreign exchange around Rs 1200 crores per annum from jute good export. Jute provides livelihood of more than 4 million farm families. It also provides direct and indirect employment to another 1 million people in the industrial sector (Anonymous, *Vision 2030*, CRIJAF, ICAR, 2011). Jute goods are eco-friendly and cheaper than competing synthetic products in terms of repeated use. In view of growing consciousness on environment protection against pollution throughout the world, it is expected that future of jute will be much brighter than now. To keep pace with the anticipated increased demand in future, a dynamic breeding strategy for increasing productivity is to be adopted well ahead of time.

Of the two cultivated species of jute, *tossa* (*Corchorus olitorius* L.) and *white* (*C. capsularis* L.) former is higher yielder and occupies nearly 90 % of jute growing areas in India. In spite of continuous efforts to break the yield barrier through conventional breeding methods, productivity remains almost stagnant for decades long since the release of JRO 524, the most popular variety till date. Therefore, further gain would require other method of breeding like heterosis breeding keeping eye on its commercial use. Of the available breeding techniques, hybrid breeding, at present days, has fared well in breaking the yield plateau of many self pollinated crops. For developing hybrids in most of these self pollinated crops, cytoplasmic male sterility is being used. In absence of any male sterility system in *tossa* jute, F_1 hybrid seed production in commercial scale with hand emasculation and hand pollination like that in cotton (Mehta and Patel, 1983) can be accomplished in commercial scale, if it is found economic.

Whatever magnitude of heterosis in *tossa* jute was reported earlier that are mainly for fibre yield based on single plant and unilocation study. Ahmed (1972) reported 60.14% better parent F_1 heterosis, while Basak *et al*. (1974) reported 65.1% and 31.4% highest magnitude of better and best parent heterosis respectively. Roy and Ghosh Dastidar (2004) reported 18.2 % and 7.6 % F_1 and F_2 standard heterosis respectively. No information on heterosis study in population level from multilocation over years test is yet available.

This paper aims to report extent of standard heterosis in F_1 hybrids against high yielding inbred checks (both standard varieties and elite selection) for fibre yield in *tossa* jute from experiments conducted over locations and years (seasons) in population level.

Materials and Methods

Experimental materials and seed production

Five high heterotic F_1 experimental hybrids; namely, Russian Green × JRO 620 (HJ 1), Russian Green × Sallyout (HJ 2), JRO 632 × Russian 1 (HJ 3), Tanganyika 1 × O 50-4963 (HJ 4), Tanganyika 1 × Russian Green (HJ 5) and three high yielding inbred checks; namely, JRO 632, JRO 36 E, JRO 524 constituted the experimental materials. Hybrid combinations were chosen from the previous study conducted at Central Research Institute for Jute and Allied Fibres (CRIJAF, ICAR), Barrackore, W. Bengal, India and reported by Basak *et al*. (1975). Seeds of check varieties and seven parental lines of test hybrids (JRO 620, JRO 632, Russian Green, Sallyout, Russian 1, O50-4963 and Tanganyika 1) were collected from CRIJAF. Besides Tanganyika 1 and JRO 36 E, all other genotypes are premature flowering susceptible type; that is, if sown before middle of April they flower at juvenile growth stage.

Sufficient quantity of seed of five F_1 hybrids and three check varieties was produced previous to each of three experimental years. Hybridization was done with hand emasculation and hand pollination. Seeds of check varieties were produced by controlled selfing. Pods, at maturity, were collected separately for each hybrid combination and check entry, threshed, cleaned and sun dried thoroughly for conducting experiments in the following pre-wet season

Experimental sites and season

Six experimental sites; namely, Masunda (L1), Hamidpur (L2), Chandipur (L3), Iswarigachha (L4), Horpur (L5) and Madhabpur (L6) distributed across two subdivisions in the main *tossa* jute growing belt were selected. First 4 locations are situated in Barasat and latter two in Brrackpore subdivisions of district North 24 Paraganas. Experiment was conducted for three consecutive years as pre-wet season crop.

Experimental design and layout

Experimental area in each location was prepared by deep ploughing followed by harrowing and laddering. Experiment was run in RBD with four replications. Plot size allotted for each treatment in each replication was 5. 0 m. by 4. 8 m.

Crop management

In each site recommended dose of fertilizers; that is, N (urea), P2 O5 (single super phosphate) and K2 O (muriate of potash) @ 60 : 30 : 30 kg ha^{-1} was applied in the experimental area in each year. Half of urea and whole of super phosphate and muriate of potash were applied as basal dose before last ploughing during land preparation. Other half of urea was applied as topdressing in two equal doses, the first at 3 weeks and the second at 6 weeks after sowing. Seeds were sown with seed-drill @ 3. 0 kg.(approx.) seeds ha^{-1}. Row to row and plant to plant distance was maintained 30 cm and 5-7 cm respectively. Sowing was completed within 6 consecutive days starting from second fortnight of April. Hand weeding was done just before first topdressing followed by thinning. Other recommended agronomic practices were followed to raise a healthy crop.

Harvesting and data recording

In each site, crop was harvested around 120 days of crop growth. Fresh harvest was left on the field for about a week for shedding of green leaves. Labeled stem-bundles were then put under a pool of water for retting. After proper retting, fibres were extracted by whipping the stems on the surface of water. Extracted fibres were washed, thoroughly sun-dried and weighed to measure yield plot^{-1} in kg.

2.6. Statistical analysis

Variance analysis of fibre yield data was conducted by the method outlined by Verma *et al.* (1987) using plot yield (transformed in q ha^{-1}) to find out the significance of treatment effects.

Percent standard heterosis of all five F_1 hybrids against the standard checks was calculated using the following formula:

Standard Heterosis (%) = (F_1 – Standard Check) (100) / Standard Check

Least Significance of Difference (LSD) was computed from the pooled error to test the significance of difference for fibre yield between the hybrids and the checks.

Results and Discussion

To be commercially successful, a *tossa* jute hybrid variety should exhibit high fibre yield and high magnitude of heterosis with a low degree of fluctuation in performance when grown over a range of environments. Objective of this paper is to discuss the fibre yield potential and the magnitude of standard heterosis of 5 experimental F_1 hybrids in population level over locations and years (environments). Results of stability study for fibre yield of these hybrids and inbred checks across environments will be presented elsewhere. In a diallel experiment conducted over environments, conventionally, data on different characters including yield are recorded on the basis of small number of randomly selected plants and heterosis is calculated in respect of mid-parent and/or better and/or best parent. Sampling error and small sample size, mostly, inflate the estimates in such studies. Therefore, for evaluating commercial promise, it is necessary to reevaluate the performance and status of heterosis of these 5 high heterotic crosses against the standard inbred check variety in replicated trials under population level over the environments.

Mean fibre yield (q ha^{-1}) of 5 F_1 hybrids and 3 inbred checks over 6 locations (years pooled) is presented in Table 1. From the results of 3 test environments; that is, over locations, over years and over combined location + year environments, it is observed that fibre yield of two hybrids; namely, HJ 4 (35.7 q ha^{-1}) and HJ 5 (36.3 q ha^{-1}) are significantly ($P> 0.05$) superior to all 3 checks. Further, the latter hybrid is significantly ($P> 0.05$) superior to the former for mean fibre yield. Hence, based on superior yield performance the hybrid HJ 5 appears to be the best over the environments.

Combined analysis of variance over locations and years shown in Table 2 reveals that mean squares (MS) for both locations (MS=871.29) and years (MS=16.30) are significant ($P>0.01$). Variations observed between locations may be ascribed to the differences in soil types, initial fertility status of the soils and "unspecified abiotic stress" mostly caused by farmers' choice for different cropping systems, injudicious use of chemical fertilizers specifically nitrogen. Whereas, climatic difference like temperature, photosynthetically active radiation, total rain fall and distribution of pre-monsoon shower etc. may be the major factors causing seasonal difference between the experimental years. All these factors might have differentially influenced the growth physiology of genotypes, ultimately causing variation in yield attributing characters and so yield. Therefore, test environments sampled were appropriate for the present study.

Significant ($P>0.01$) entry variance (MS= 445.712) against the error indicates presence of large difference among the test entries. All the interactions, both first (MS for entry x location = 45.20 and entry

TABLE 1. Mean fibre yield (q ha $^{-1}$) of 5 selected F_1 hybrids and 3 checks over 6 locations (Years pooled)

Sl. No.	Hybrids	Mean fibre yield (q ha $^{-1}$) over locations Masunda (L1)	Hamidpur (L2)	Chandipur (L3)	Iswarigachha (L4)	Horpur (L5)	Madhabpur (L6)	Over all mean
1.	Rssian Green x JRO 620 (HJ 1)	28.1	28.0	38.4	29.0	27.5	27.9	29.8
2.	Russian Green x Sallyout (HJ 2)	25.4	30.8	36.6	27.3	30.1	30.5	30.1
3.	JRO 632 X Russian 1 (HJ 3)	34.5	30.3	38.5	28.4	32.2	29.4	32.2
4.	Tanganyika 1 x O50-4963 HJ 4)	35.2	35.9	40.9	33.4	34.7	34.4	35.7
5.	Tanganyika 1 x Russian Green (HJ 5)	34.5	34.6	42.3	33.4	37.2	36.0	36.3
	Checks							
6.	JRO 632	33.8	28.5	35.7	30.5	29.6	28.4	31.1
7.	JRO 36 E	35.2	31.7	38.1	31.4	34.9	31.1	33.7
8.	JRO 524	27.8	31.7	34.8	30.0	32.1	30.9	31.2
	Environmental Index	-0.720	-0.851	6.024	-2.170	-0.592	-1.692	
	$LSD_{(0.05)}$	2.3 q ha $^{-1}$	2.1 q ha $^{-1}$	2.0 q ha $^{-1}$	2.4 q ha $^{-1}$	2.4 q ha $^{-1}$	2.2 q ha $^{-1}$	1.3 q ha $^{-1}$

TABLE 2. Mean squares from general analysis of variance for fibre yield of 5 selected F_1 hybrids and 3 checks over 18 environments (6 locations x 3 years)

Source	df	Mean Squars
Replication within location and year	54	33.394
Location	5	871. 286 **
Year	2	16. 297 **
Entry	7	445. 712 ** ∫∫●● ++
F_1 hybrid	4	675. 945 **
Check	2	158. 065 **
F_1 hybrid *vs* Check	1	100. 064 **
Entry × Location	35	45. 203 **
Entry × Year	14	48. 429 **
Location × Year	10	104. 831 **
Entry × Location × Year	70	86. 421 **
Error	378	2. 230

** Significantly different (P < 0.01) against error.

∫∫,●● , ++ Significantly different (P < 0.01) against entry x location, entry x year, and entry x location x year interactions respectively.

× year = 48.43) and the second order interactions are significant (P>0.01). Between first order interaction variance for entry × year interactions turned out to be 1.1 times greater than that for entry × location suggesting equal importance of both locations and years in a hybrid testing programme for *tossa* jute. Entry × location × year interactions (MS= 86.42) were observed more important than either of the first order interactions pining towards ranking of entries across locations is not consistent between years. In other words entries were influenced by the environmental effects either of locations or years and these two environmental effects in combination, possibly reduced the expression of potential heterosis more in the location and year combined environments. Studies of Walton (1971) on spring wheat and Gyawali *et al.* (1968) on winter wheat reported that for guaranteed better expression of heterosis genotype-environment (G-E) interactions are to be reduced. Variance components for the second order interactions are relatively small compared to the entry variance. Hence, significant genetic difference between entries is clearly established. Significant (P>0.01) difference between hybrids (MS=675.94) and among checks (MS=158.06) is also evident. Mean squares (100.06) for hybrid *vs.* check contrast are found significant (P>0.01) indicating presence of large difference between the performance of heterozygotes and homozygotes.

Swaminathan *et al.* (1972) reported from different estimates that for heterosis in a self pollinated crop to be economically advantageous, it must give 25 percent more yield than the best inbred commercial variety. Accordingly, check entries were revisited in view of hybrid comparison. The highest yielding check, JRO 36 E has not yet been officially released. Therefore, it has not been recommended for commercial cultivation. The other check JRO 632 is a released variety that dominated the jute growing areas before the release of JRO 524. But at present, it is almost out of cultivation due to difficulties in fitting

Table 3. Percent heterosis of 5 selected F_1 hybrids against 3 inbred checks over 6 locations (Years pooled)

LOCATION WISE HETEROSIS (%) AGAINST EACH CHECK

Hybrids / Checks	Masunda			Hamidpur			Chandipur			Iswarigachha			Horpur			Madhabpur			Over all Mean Heterosis against each Check		
	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524
Russian Greenx JRO 620	-16.9*	-20.2*	1. 1	1.7	-11.7*	-11.7*	-1.8	-10.3*	-9.7*	- 4.9	-7.6	-3.3	-7.1	-21.2*	-14.3*	-1.8	-10.3*	-9.7*	-3.9*	-11.6*	-4.5*
Russian Greenx Sallyout	- 24.8*	-27.8*	- 8.6*	8.1	-2.8	- 2.8	7.4	-1.9	-1.3	-10.5*	-13.1*	-9.0 *	1.7	-13.7*	-6.2	7.4	-1.9	-1.3	-2.9*	-10.7*	-3.5*
JRO 632x Russian 1	2.1	-2.0	24.1*	6.3	-4.4	-4.4	3.5	-5.5	-4.8	-6.9	-9.6*	-5.3	8.8*	-7.7*	0.3	3.5	-5.5	-4.8	3.9*	-4.4*	3.2*
Tanganyika 1x O50-4963	4.1	0.0	26. 6*	26.0*	13.2*	13.2*	21.1*	10.6*	11.3*	9.5*	6.4	11.3*	17.2*	-0.6	8.1*	21.1*	10.6*	11.3*	15.2*	5.9*	14.4*
Tanganyika 1x Russian Green	2.1	-2.0	24.1*	21.4*	9.1*	9.1*	26.8*	15.8*	16.5*	9.5*	6.4	11.3*	25.7*	6.6	1 5.9*	26.8*	15.8*	16.5*	17.1*	7.7*	16.3*
LSD (0.05)		2.3 q ha^{-1}			2.1 q ha^{-1}			2.0 q ha^{-1}			2.4 q ha^{-1}			2.4 q ha^{-1}			2.3 q ha^{-1}			0.49 q ha^{-1}	

it to the rice based cropping system. Therefore, magnitude of heterosis of experimental hybrids is finally reported in respect of the dominant commercial inbred check variety; that is, JRO 524.

Within location range of percent heterosis over JRO 524 (Table3) varies from - 8.6 to 26.6 (L1), - 11.7 to 13.2 (L2), 5.2 to 21.6 (L3), - 9.0 to 11.3 (L4), - 14.3 to 15.9 (L5) and - 9.7 to 16.5 (L6). It is most likely that difference in genetic potentiality of hybrids is the main source causing variation in yield within a location. Between locations percent heterosis ranges from - 14.3 to 10.3 for HJ1, - 9.0 to 5.2 for HJ2, - 5.3 to 24.1 for HJ3, 8.1 to 26.6 for HJ4, 9.1 to 24.1 for HJ5. Environmental index (EI) for L4 and L3 are - 2.170 and 6.024 representing poorest and richest environment respectively while other values lie in between the two extremes indicating a range of intermediate location-environments. It is observed from the corresponding EI of locations that yield advantage of hybrids, in general, is higher in the rich environments and lower in poor environments. For the present investigation, since locations within a district are not separated by long distance, difference in yield advantage of hybrids across locations within a district appears to be influenced most by the "unspecified abiotic stress" rather than other factors especially in lower yield sites.

The hybrid; namely, HJ 4 is observed to show high yield advantage in lower yielding sites suggesting that it is more tolerant to the "unspecified abiotic stress". And, conversely, the yield advantage of another hybrid, HJ 5 at the higher yield sites suggests that this hybrid is more responsive to favorable growing conditions. While reviewing genetic progress in yield of United State maize, Duvick (2005) observed that the yield advantage of the newer hybrids (compared with the older hybrids) at the lower yield sites indicates that the newer hybrids were more tolerant to "unspecified abiotic stress" than were the older hybrids. And conversely, the yield advantage of the newer hybrids at the higher yield sites showed that they also were more responsive to favorable growing conditions.

It is observed from the percent heterosis over locations and years combined data (Table 3) that two highest yielding hybrids i.e. HJ 4 and HJ 5 also exhibit highest yield advantage of 14.4 and 16.3 percent respectively over JRO 524. This proves that it is possible to develop *tossa* jute hybrid with high mean yield and high heterosis. In cotton, heterosis of 50% over the popular inbred variety and 20% over the popular hybrid is considered significant for development of hybrid (Singh *et al.,* http://www.cicr.org.in). In rice, 35 percent higher magnitude of heterosis against the most popular and widely cultivated variety is normally considered for recommendation (Yuan, 2003). In jute, if a nominated inbred entry exhibits 8-10 % higher yield than that of the popular check variety in the All India Coordinated Trials, it is recommended for release; provided no negative character like high susceptibility to any major disease remains associated. If the above yield level in jute is considered as the 'benchmark value' for improvement in yield, above two hybrids show encouraging results in favour of heterosis breeding. Still the present magnitude of heterosis in this species of jute appears inadequate when placed against that of cotton and rice. However, prior to recommendation for commercial cultivation, economics of the present level of realized heterosis is to be assessed in the context of F_1 hybrid seed production cost and recommended seed rate.

These 5 hybrids, as mentioned earlier, were selected as high heterotic on the basis of their performance in a diallel cross. Other than HJ 4 and HJ 5, rest 3 hybrids (HJ 1, HJ 2 and HJ 3) exhibited negative and / or non-significant yield advantage over JRO 524 in most of the locations (years pooled). It is, therefore, observed that better or even the best parent heterosis assessed from unilocation over single or more years test based on small number of sample-plants, may not replicate the same result in population level against the dominant commercial variety in a multilocation over year test. Hence, results of realized heterosis in a diallel cross experiment are suggestive but not decisive.

Inheritance study from 8-parent diallel cross in *tossa* jute that included these high heterotic combinations, indicated importance of both additive and non-additive genetic control for fibre yield (Basu, 1985). Further calculation of his data revealed that additive genetic variance was 1.5 times larger than the nonadditive component. Earlier studies by Jana (1972), Basak *et al.* (1973), Saha *et al* (1996), it was reported that additive genetic control for fibre yield was either equal to or greater than the nonadditive part. Senior author of the present communication also observed in a 10- parent diallel cross experiment that additive genetic variance is 1.4 times greater than that of non-additive genetic component for fibre yield, in the same species (unpublished). In majority of the reports in autogamous crops including jute, major genetic control of yield was reported due to additive genetic effects suggesting breeding methods designed to accumulate favourable genetic factors in homozygous genotypes appear to remain a more appropriate procedure for improvement than the commercial production of hybrids (Matzinger *et al.*, 1962, Venkateswarlu and Singh, 1981, Saha *et al.*, 1996. Yawen and Liangzheng, 2001). Heterosis breeding was suggested for the crops where major control of character to be altered is due to nonadditive variance (Nirania *et al.*, 1991, Ahuja and Tuteja, 2000, Bhatt *et al.*, 2001, Verma *et al.*, 2004, Singh and Asati, 2011).

Contrary to the above genetic concepts, Arunachlam (1977) reported that heterosis for characters governed by one gene are attributable to dominance. Whereas, it is possible to realize heterosis on the basis of additive genetic effects and its interactions alone for the characters, that are govern by more than one gene. In support of this, Reddy and Arunachalam (1981) presented experimental evidence for the expression of high heterosis without dominance or their interactions in pearl millet. They further suggested that more than genetic and geographic divergence, general combining ability (*gca*) divergence would be needed for bringing about high heterosis. While reviewing 'Genetics and Breeding of Jute', Basak (1993) suggested that additive genetic variance acts as the 'bench mark value' for heterosis and if it is raised, total heterosis would be increased. So it is felt that for elevating the heterosis level further from the present realized level in this species of jute, emphasis is to be paid for increasing variability for *gca* along with maintaining genetic diversity. So presence of high *gca* for yield should not be considered as deterrent for heterosis breeding, rather, this advantage is to be capitalized following suitable breeding method, available to self pollinated crop for realizing high heterosis.

There is a constant need to develop more potential hybrids and adopt novel approaches for improving hybrid performance. In cross pollinated crops like maize heterotic populations are developed and exploited through population improvement schemes meant for improving combining ability. Such programmes are integral part of hybrid maize breeding programme and used further to obtain more potential hybrids. Studies have shown that in cotton it has become possible to adopt these concepts with suitable modifications to suit the mating system of self pollinated crops (Patil and Patil, 2003 and Patil *et al.*, 2007).

Jute being a self pollinated crop, it appears, if a population improvement scheme like cotton can be adopted for this species of jute, genetic as well as *gca* variability within the derived population will be increased significantly. If so, genetically divergent transgressive segregants with high positive *gca*, that are likely to appear within the improved population, can be used as parents to develop more potential hybrid (s).

Conclusions

It is clear from the present investigation that results of a diallel experiment that helps to identify high heterotic hybrid (s) against the mid- and/or better and/or even the best parent are indicative but not decisive. For commercial promise, hybrids thus selected, should be reevaluated through multilocation over year trials in population level. It is observed that consistency in heterosis expression over environments is a concern to be addressed. However, two hybrids, from this study; namely, Tanganyika1 × O50-4963 and Tanganyika1 × Russian Green have been identified which showed significant high mean fibre yield and significant high standard heterosis over JRO 524, the widely adapted variety under cultivation. Hence, heterosis breeding would be of great promise for breaking the yield plateau in *tossa* jute.

It appears, that the population improvement approach as suggested by Patil and Patil (2003) and Patil *et al.*, (2007) requires to be practiced in this species of jute for developing improved population possessing greater genetic and *gca* variability. And transgressive segregants that would appear within improved population, if used as parents in hybrid development, still higher level of F_1 heterosis is possible to realize.

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Literature Cited

Ahmed, S. U. 1972. Effect of plant height on fibre yield in jute (*Corchorus olitorius* L.) *Crop Sci.*, **12**: 386-387.

Anonymous. 2011. Scenario of jute and allied fibres. *Vision 2030, CRIJAF (1CAR)*, Barrackpore, W. Bengal, India, p. 1-4.

Arunachalam, V. 1977. Heterosis for characters governed by two genes. *J. Genet*., **63**: 15-24.

Ahuja S. L. and Tuteja O. P. 2000. Variability and association analysis for chemical components imparting resistance to *Gossypium hirsutum* cotton. *J. Cotton Res. Dev.*, **14**:19-22.

Basak, S. L., Choudhury, B. B. and Jana, M. K. 1973. Effect of fertilizer on combining ability of jute. *SABRAO News Let.*, **5**: 15-21.

Basak, S.L., Jana, M.K. and Paria, P. 1974. Approaches to genetic improvement of jute. *Indian J. Genet.*, **34A**: 891-900.

Basak, S. L., Basu, M. S. and Saha, A. (1975). Exploitation of hybrid vigour in jute (*Corchorus olitorius* L.). *Annual Report, CRIJAF (ICAR)*, Barrackpore- , India, 4 p.

Basak, S. L. 1993.Review on the genetics and breeding of jute. *An International Jute Organization (IJO) publication*, Dhaka, Bangladesh.

Basu, M. S. 1985. Genetic studies of some growth parameters in jute (*Corchorus olitorius* L.). *Ph. D. Thesis* (unpublished), Faculty of Agriculture, University of Calcutta, W. Bengal, India.

Bhatt, R. P., Biswas, V. R. and Kumar, Narendra. 2001. Combining ability studies in tomato (*Licopersicon esculentum* Mill.) under mid hill conditions of Central Himalaya. *Indian J. Genet.*, **61**: 74 – 75.

Duvick, D. N. 2005. Genetic progress in yield of United States maize (*Zea mays* L.). *Maydica*, **50**: 193-202.

Gyawali, K. K., Quelset, C. O. and Yamazaki, W. T. 1968. Estimates of heterosis and combining ability in winter wheat. *Crop Sci.*, **11**: 422-424.

Jana, M. K. 1972. Genetic analysis of some quantitative traits in jute. *Ph. D. Thesis* (unpublished). Kalyani Univ., W. Bengal, India.

Matzinger, D. F., Mann, T. J. 1962. Hybrid among flue-cured varieties of *Nicotiana tabacum* in the F1 and F2 generations. *Tob. Sci.*, **6**: 125-132.

Mehta, N. P. and Patel, C. T. 1983. Hybrid seed production technique for exploitation of heterosis in cotton. *Indian Far.*, **Dec**.: 23-31.

Nirania, K.S., Jain, P.P. and Sing, J.P., Tuteja, O.P. and Sandhu, G.S. 1991. Heterosis and combining ability analysis in upland cotton.. *J. Indian Soc. Cotton Improv.,* **16**: 82-85.

Patil, S.S. and Patil, S. A. 2003. Role of improving combining ability in increasing performance of cotton hybrids. *Third World Cotton Research Conference,* 9-13 March 2003, Cape Town, South Africa: pp. 234-238.

Patil, S. S., Patil, S. A., Ramakrishna, V., Deepakbabu, H. and Mallikarjun, H. B., 2007, *Approaches of improving combining ability for enhancing performance of cotton hybrids*. Fourth World Cotton Research Conference, 10-11th September 2007, held at Lubbock, Texas, U.S.A.

Reddy, B. B. and Arunachalam, V. 1981. Evaluation of heterosis through combining ability in pearl millet I Single crosses. *Indian J. Genet*. **41**: 59 - 65.

Roy, S. and Ghosh Dastidar, K. K. 2004. Role of induced mutation on the utilization of residual heterosis in jute (*Corchorus olitorius* L.). *Indian J. Genet.*, **64**: 46-48.

Saha, A., kumar, D. and Basak, S. L. 1996. Diallel cross analysis over years for yield and its component characters in tossa jute (*Corchorus olitorius* L.). *Bangladesh J. Bot.*, **25**: 59-63.

Singh, A. K. and Asati, B. S**.** 2011. Combining ability and heterosis studies in tomato under bacterial wilt condition. *Bangladesh J. Agril. Res.* **36**: 313-318.

Singh, P., Kairon, M. S. and Singh, S. B. *Breeding hybrid cotton*. *CICR Tch. Bull.*, **14** (http://www.cicr.org.in).

Swaminathan, M. S., Siddiq, E. A. and Sharma, S. D. 1972. Out look for hybrid rice in India. Rice Breeding. IRRI, Los Banos, Philippines, p. 609 -613.

Venkateswarlu, S. and Singh, R. B. 1981. Heterosis and combining ability in peas. *Indian J. Genet*. **41**: 255-258.

Verma, M. M., K. S. Gill and Virk, D.S. 1987. Genotype – Environment Interaction – Its Management and Significance in Plant Breeding. Communic. Cent., Punjab Agric. Univ., Ludhiana, India, p 13 – 48.

Verma, S. K., Ahuja, S. L., Tuteja, O. P. and Monga, D. 2004. Line x tester analysis of yield, its components and fibre quality traits in cotton. *J. Indian Soc. Cotton Improv.,* **29**: 151-157.

Walton, P. D. 1971. Heterosis in spring wheat. *Crop Sci.*, **11**: 122 - 124.

Yawen, Z. and Liang Zheng, C. 2001. Combining ability and heterosis in forage barley. *Indian J. Genet.*, **61**: 71 – 73.

Yuan, L. P. 2003. Recent progress in super hybrid rice breeding in China. Hybrid rice for food security, poverty alleviation and environmental protection. *Proceedings of the 4th International Symposium on Hybrid Rice*, 14-17 May 2002, Hanoi, Vietnam. Los Banos (Philippines): International Rice Research Institute, 3-6 pp.

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Assessment of Site - Specific Primary Nutrient Element Requirements for Potato (*Solanum Tuberosum* L.) Under Lower Gangetic Plains of West Bengal

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Abstract

Field experiments were conducted during *rabi* seasons of 2012-13, 2013-14, 2014-15 and 2015-16 at C-unit research farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to determine site-specific primary nutrient element requirements for potato under lower Gangetic plains of West Bengal. The experiment was laid out in a randomized block design with four replications having seven treatments *viz.* T_1-50% RDF of NPK, T_2-100% RDF of NPK, T_3-150% RDF of NPK, T_4-Without N fertilizer (PK), T_5-Without P (NK), T_6-Without K (NP) and T_7-Without NPK (Absolute control). Experimental results revealed that plant emergence of potato was not affected by varied level of nutrients, and it was above 96.31%. Grade-wise tuber production was significantly influenced by nutrient levels, and Kufri Jyoti produced maximum total tuber yield (24.74 t ha^{-1}) with 150% RDF which was found statistically at par with 100% RDF of NPK. However, the crop fertilized with 100% RDF gave highest net return (Rs. 47806). Among the three primary nutrient elements, N-omission plots recorded highest and drastic reduction in marketable tuber (50-75g and > 75 g) yield. Results of the experiment revealed that, highest agronomic efficiency (AE), apparent recovery (ARE) of N, P and K were observed under plots receiving 50% RDF of NPK closely followed by 100% RDF of NPK and lowest agronomic efficiency, apparent recovery of P and K were observed in N- omission plots as because N-omission drastically reduced the uptake of nutrients by potato plant. On the other hand, highest physiological efficiency of N was observed in N-omission plots and highest physiological efficiency of P and K were observed in K- omission plots. Physiological efficiency of potato variety K. Jyoti gradually reduced with the increase in applied fertilizer doses starting from 50% to 150% RDF of NPK, which means K. Jyoti variety could not fully or totally transformed the increased amount of nutrient doses into economic yield.

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. One of the major problems in potato cultivation in this area is use of inappropriate doses of fertilizers. This situation can be overcome by adopting site specific nutrient management practices. Site specific nutrient management planning is required to improve crop yield, environmental quality and economic return. Potato crop being highly exhaustive and responsive, and having high rate of production per unit area and time, requires higher amount of nutrients especially nitrogen (N). On an average, a 90 days potato crop producing 20 tonnes tubers per hectare requires about 100 kg nitrogen to be removed in the form of tuber and haulm. Nitrogen uptake on per day basis is sometime even more than 1.5 kg ha^{-1} during active growth period (Kumar and Trehan, 2012). Nitrogen plays an important role in crop growth and development resulting in increased size and number of tubers ultimately enhancing total yield (Kumar *et al.,* 2007). In addition, under or oversupply of N may affect tuber production. Moreover, maintaining an adequate supply of N in the root zone of potato without leaching is important for optimal production of marketable quality tubers. On the contrary, excessive application leads to delayed maturity, poor tuber quality and occasional reduction in tuber yield (Alva, 2004). Agronomic research on macro-nutrient management aspect showed that some newly released potato cultivars for processing requires approximately 150% higher nitrogen and potassium over current table-purpose potato cultivars. Recent diagnostic survey also indicates that in many intensively cultivated areas, farmers have resorted to use of greater than the recommended dose of fertilizer (RDF), particularly N to maintain crop productivity. Keeping the above facts in view, this experiment was initiated with the objectives to develop a site specific primary nutrient element management of potato for getting higher yield, to assess the most yield determining primary nutrient element for potato, to determine the various nutrient use efficiencies and to analyse the economic return of various primary nutrient element management practices under lower Gangetic plains of West Bengal.

Materials and Methods

Field experiments were conducted for four 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* 2012-13, 2013-14, 2014-15 and 2015-16. 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 randomized block design with four replications having seven treatments *viz.* T_1: 50% RDF(recommended dose of fertilizer) of NPK, T_2: 100% RDF of NPK, T_3: 150% RDF of NPK, T_4: Without N fertilizer (PK), T_5: Without P (NK), T_6: Without K (NP), and T_7: Without NPK (Absolute control) with a plot size of 5 m X 3 m. The crop was planted on fourth week of November, 2012-13, 2013-14, 2014-15 and 2015-16 respectively. Tubers weighing 30–40 g each were planted in the furrows with a depth of planting of 3–4 cm and spacing of 60 cm X 20 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. Dimethoate (Rogor) @ 0.1% was also sprayed (twice) at 45 and 65 DAP for controlling aphids and other insects. Haulms were cut in the last week of February in all the four seasons after the crop attained maturity. Harvesting was done 15 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 yield (t ha^{-1}) and total tuber yield (t ha^{-1}) were recorded at harvest from each net plot area. N, P and K use efficiency was calculated using following formulae cited by Singh and Singh (2012).

Agronomic efficiency (AE) = Y_n-Y_0 / N_a

Physiological efficiency (PE) = Y_n-Y_0 / NU_n – NU_0

Apparent Recovery efficiency (ARE) =(NU_n – NU_0/ N_a) X 100

where, Y_n refers to tuber yield of potato with nutrient, Y_0 refers to tuber yield of potato without nutrient and NU_n refers to nutrient uptake with nutrient, NU_0 refers to nutrient uptake without nutrient, N_a is nutrient applied. All values are in kg ha^{-1}. Estimation of nutrient-use efficiencies followed the framework described by Cassman *et al.* (1998). Nutrient (N, P and K) concentrations in potato tuber and haulm were analysed following standard procedures. The economic parameters (cost of cultivation, gross returns and net returns) were worked on the basis of prevailing market prices of inputs and outputs. Nutrient uptake was calculated by multiplying the yield with the concentration of particular nutrient. Analysis of variance of the data in the experimental design and comparison of means at pd≤0.05 were carried out, using MSTAT-C software.

Results and Discussion

Effect on plant emergence and yield

Experimental results revealed that plant emergence of potato was not significantly influenced by nutrient management practices. It ranged from 96.31 to 98.88%. Experimental results also revealed that grade wise tuber production of potato was significantly influenced by nutrient management practices (Table. 1). The potato variety Kufri Jyoti produced maximum total tuber yield (24.74 t ha^{-1}) and marketable tuber (50-75g and > 75 g) yield with 150% RDF of NPK which was found statistically at par with 100% RDF of NPK (24.07 t ha^{-1}). Getting more tuber yield with increasing fertilizer dose was also supported by Sarkar *et al*. (2011). Response to higher fertilization may be linked to the increase in total leaf area which in turn increased the amount of solar radiation intercepted, and more photo-assimilate might have been produced and assimilated to the tubers (Baishya *et al.,* 2013). The lowest total tuber yield (8.28 t ha^{-1}) was recorded in control plot. Among the three primary nutrient elements, N-omission plots recorded highest and drastic reduction in marketable tuber (50-75g and > 75 g) yield might be owing to lower leaf area index acted over the tuber bulking period resulting in reduced dry-matter accumulation and lower tuber bulking rate as reported my Mozumder *et al.* (2014). K-omission did not affect the total tuber yield of potato significantly might be due to sufficiency of potassium in the native soil and which recorded a total tuber yield of 22.47 t ha^{-1}. Among the three primary nutrient elements nitrogen was found to be the most yield limiting primary nutrient element in potato.

Effect on nutrient uptake

Experimental results revealed that the higher uptake of nutrients (N, P & K) by potato cultivar Kufri Jyoti was the resultant of higher yield (Table 2 and 3). Nutrient uptake of potato was highly influenced by various nutrient management practices. Nutrient uptake (N, P & K) by tubers and haulms of potato were gradually increased with increasing levels of N,P and K application up to 150% RDF of NPK. Similar type of finding was also reported by Das *et. al.* (2015). The lowest uptake of nutrients were recorded in control plots. Among the three omission treatments, nitrogen omission recorded drastic reduction in the uptake of all the three primary nutrient elements.

Effect on nutrient uptake efficiencies

Results of the experiment revealed that, highest agronomic efficiency (AE), apparent recovery (ARE) of N, P and K were observed under plots receiving 50% RDF of NPK closely followed by 100% RDF of NPK (Table 4) and lowest agronomic efficiency, apparent recovery of P and K were observed in N- omission plots as because N-omission drastically reduced the uptake of nutrients by potato plant. Agronomic efficiency decreased linearly with every incremental dose of N,P, and K starting from 50% to 150% RDF of NPK confirming the findings of Love *et al.* (2005), Kumar *et al.* (2008) and Mozumder *et al.* (2014). Whereas, highest physiological efficiency (PE) of N was observed in N- omission plots and highest physiological efficiency of P and K were observed in K- omission plots. Physiological efficiency of potato variety K. Jyoti gradually reduced with the increase in applied fertilizer doses starting from 50% RDF of NPK to 150% RDF of NPK, which means K. Jyoti variety could not fully or totally transformed the increased amount of nutrient doses in to economic yield as PE represents the ability of a plant to transform nutrients acquired from fertilizer into economic yield.

Economics

The results showed that potato variety Kufri Jyoti fertilized with 100% RDF of NPK gave highest net return (Rs. 47806) (Table 5). Next best net return (Rs. 44519/-) was recorded with 150% RDF of NPK. The lowest net return was recorded in N- omission plots. Thus, from economic point of view100% RDF of NPK for potato variety Kufri Jyoti proved to be the best for farmers' practice.

Table 1. Effect of nutrient management practices on emergence and grade wise tuber yield of potato (Pooled data of 4 years)

Treatment	Emergence (%)	Yield of 0-25 g tubers (t ha^{-1})	Yield of 25-50 g tubers (t ha^{-1})	Yield of 50-75 g tubers (t ha^{-1})	Yield of > 75 g tubers (t ha^{-1})	Total tuber yield (t ha^{-1})
T_1	97.69	2.35	3.49	5.17	6.05	17.07
T_2	98.21	2.77	4.04	6.82	10.30	24.07
T_3	98.83	3.05	4.53	6.40	10.59	24.74
T_4	98.88	1.70	2.89	3.36	1.76	9.70
T_5	97.60	2.15	4.21	5.53	5.97	17.86
T_6	96.31	3.17	4.41	7.04	7.86	22.47
T_7	98.25	1.71	2.45	2.98	1.14	8.28
SEm(±)	1.08	0.18	0.31	0.40	0.80	0.82
CD (P=0.05)	NS	0.52	0.95	1.2	2.4	2.4

Table 2. Effect of nutrient management practices on dry matter yield of potato (Pooled data of 4 years)

Treatment	Dry matter yield of tuber (t ha^{-1})	Dry matter yield of haulm (t ha^{-1})
T_1	4.18	2.26
T_2	5.86	3.26
T_3	6.01	3.42
T_4	2.40	1.19
T_5	4.38	2.32
T_6	5.48	3.10
T_7	2.07	0.97
SEm(±)	0.18	0.12
CD (P=0.05)	0.50	0.32

Conclusion

Thus, it can be concluded that, though grade-wise tuber production of potato variety Kufri Jyoti was significantly influenced by nutrient levels, and it produced maximum total tuber yield (24.74 t/ha) with 150% RDF which was found statistically at par with 100% RDF of NPK that recorded highest net return but agronomic efficiency, physiological efficiency and apparent recovery percentage of N,P,K of potato variety Kufri Jyoti gradually reduced with the increase in applied fertilizer doses. Among the three primary nutrient elements, omission of nitrogen recorded drastic reduction in marketable tuber (50-75g and > 75 g) yield of potato. From economic point of view100% RDF of NPK for potato variety Kufri Jyoti proved to be the best for farmers' practice.

Literature Cited

Alva, A. 2004. Potato nitrogen management. *Journal of Vegetable Crop Production*. 10(1): 97–130.

TABLE 3. Effect of nutrient management practices on nutrient uptake by tubers and haulms of potato

Treatment	Nutrient uptake by tuber ($kg\ ha^{-1}$)			Nutrient uptake by haulm ($kg\ ha^{-1}$)			Total uptake ($kg\ ha^{-1}$)		
	N	P	K	N	P	K	N	P	K
T_1	59.4	12.5	73.2	30.7	10.8	50.9	90.1	23.4	124.0
T_2	83.2	18.8	105.5	46.6	16.3	75.0	129.8	35.1	180.5
T_3	85.3	19.8	112.4	50.3	18.1	80.0	135.6	38.0	192.4
T_4	34.1	8.2	43.4	15.0	5.6	26.3	49.1	13.8	69.7
T_5	62.2	13.6	79.7	32.5	9.3	51.7	94.7	22.9	131.5
T_6	77.8	15.9	94.3	43.1	13.3	67.6	120.9	29.2	161.8
T_7	29.4	5.4	35.0	12.4	3.8	20.7	41.8	9.2	55.6

TABLE 4. Effect of nutrient management practices on agronomic efficiency, physiological efficiency and apparent recovery efficiency

Treatment	Agronomic Efficiency (AE) (kg/kg)			Physiological Efficiency (PE) (kg/kg)			Apparent Recovery Efficiency (%) (ARE)		
	N	P	K	N	P	K	N	P	K
T1	87.9	117.2	117.2	182.0	619.0	128.5	48.3	18.9	91.2
T2	79.0	105.3	105.3	179.4	609.7	126.4	44.0	17.3	83.3
T3	54.9	73.2	73.2	175.5	571.5	120.3	31.3	12.8	60.8
T4	-	9.5	9.5	194.5	308.7	100.7	-	3.1	9.4
T5	47.9	-	63.9	181.1	699.3	126.2	26.5	-	50.6
T6	71.0	94.6	-	179.4	709.5	133.6	39.6	13.3	-
T7	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0

Baishya, L.K., Kumar, M., Ghosh, M. and Ghosh, D.C. 2013. Effect of integrated nutrient management on growth, productivity and economics of rainfed potato in Meghalaya hills. *International Journal of Agriculture, Environment and Biotechnology.* 6(1): 69–77.

Cassman, K.G., Peng, S., Olk, D.C., Ladha, J.K., Reichardt, W., Dobermann, A. and Singh, U. 1998. Opportunities for increased nitrogen use efficiency from improved resource management in irrigated rice systems. *Field Crops Research.* 56(1–2): 7–39.

Das, S.K., Banerjee, H., Chakraborty, A and Sarkar, A. 2015. Production potential of newly released potato (*Solanum tuberosum* L.) cultivars under different nitrogen levels. *SAARC J. Agri.* 13 (2): 121-130.

Directorate of Agriculture, W.B. 2014. *Economic Review.* Evaluation wing, Directorate of Agriculture, West Bengal, pp. 65.

Kumar, M. and Trehan, S.P. 2012. Influence of potato cultivars and N levels on contribution of organic amendments to N nutrition. *Journal of Potato.* 39(2): 133–44.

Kumar, M., Trehan, S.P., Jatav, M.K. and Lal, S.S. 2008. Efficacy of potato (*Solanum tuberosum)* cultivars under varying levels of nitrogen and growth duration in eastern Indo-Gangeticplains. *Indian Journal of Agronomy.* 54(1): 63–68.

TABLE 5. Economics and net returns of different treatments

Treatments	Yield (t ha^{-1})	Cost of cultivation (Rs./ha) Seed	Fertilizer	Cultivation	Cost (Rs./ha) Inputs	Produce	Sale price (Rs./t)	Net return* (Rs./ha)
T1	17.07	32000	7307	50000	89307	102420	6000	13113
T2	24.07	32000	14614	50000	96614	144420	6000	47806
T3	24.74	32000	21921	50000	103921	148440	6000	44519
T4	9.70	32000	12004	50000	94004	58200	6000	-35804
T5	17.86	32000	7110	50000	89110	107160	6000	18050
T6	22.47	32000	10114	50000	92114	134820	6000	42706
T7	8.28	32000	0	50000	82000	49680	6000	-32320

* Cost of produce - Cost of inputs (cultivation)

Kumar, P., Pandey, S.K., Singh, B.P., Singh, S.V. and Kumar, D. 2007. Effect of nitrogen rate on growth, yield, economics and crisps quality of Indian potato processing cultivars. *Potato Research*. 50(2): 143–55.

Love, S.L., Stark, J.C. and Salaiz, T. 2005. Response of four potato cultivars to rate and timing of nitrogen fertilizer. *American Journal of Potato Research*. 82(1): 21–30.

Mozumder, M., Banerjee, H., Ray, K. and Paul, T. 2014. Evaluation of potato (*Solanum tuberosum*) cultivars for productivity, nitrogen requirement and eco-friendly indices under different nitrogen levels. *Indian Journal of Agronomy*. 59 (2): 327-335.

Sarkar, A., Sarkar, S., Zaman, A. and Devi, W.P. 2011. Productivity and profitability of different cultivars of potato (*Solanum tuberosum*) as affected by organic and inorganic sources of nutrients. *Indian Journal of Agronomy*. 56(2): 159–63.

Singh, A.K. and Singh, R.S. 2012. Effect of phosphorus and bioinoculants on yield, nutrient uptake and economics of long duration pigeon pea (*Cajanus cajan*). *Indian Journal of Agronomy*. 57(3): 265–69.

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