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Diversification of Crops and Cropping Systems for Sustainable Agriculture Under Changing Climate

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Abstract

Crop diversification is aimed at to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and their cropping systems and also to lessen risks under chosen agro-climatic zones. In agriculture diversification refers to the additions of new crops with or without the addition a shift from one crop or cropping in a production system. Climate change and its variability have emerged as serious concerns to present day agriculture. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment gemination, judicious use of land and water resources, sustainable agriculture development and environmental improvement (Hedge *etal.* 2003). Diversification can improves economic stability mitigates natural calamity and provides balanced food demand. Diversification plays an important role in optimizing production without having any adverse effect on natural resource base. It aims at diversity food basket and increases income of marginal farmers and promotes export possibilities.

There are number of constraints which inhibit the pace and process of diversification of various constraints, lack of rural infrastructure and appropriate technology along with inadequate institutional support and above all socio-economic constraints limit the process of diversification.

Introduction

India's food, nutritional, livelihood and economic securities continues to be predicted by the performance of agriculture sector and the situation is not likely to change in the near future. Seventy percent of the Indian population solely depends on agriculture those feed nearly 17% of the global population. About 26% of the gross national product comes from agricultural sector. Even now, nearly 72% of our population lives in rural areas and about 58% are engaged in agriculture. Out of 328.8 m ha of total geographic area, only 145 m ha is available for cultivation which has to sustain approximately1.20 billion of population.

In the changing agricultural scenario during globalization agriculture in India has to face new challenges to compete at the global level in many agricultural commodities. Indian agriculture is now facing second generation problems like rising on lowering of water table, nutrient imbalance, soil degradation, salinity, resurgence of pasts and disease, environmental pollution and decline in form profit (Reddy and Suresh, 2009). Crop diversification shows lot of promise in alleviating these problems through fulfilling the basic needs and regulating farm income, with standing weather aberrations, controlling price fluctuations, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, environmental safety and creating employment opportunity (Gill and Ahlawat, 2006).

India has high population pressure on land and other resources to meet its food and development needs. The massive increase in population and substantial income growth demands an extra food grain production annually. The natural resource base of land, water and biodiversity is under severe pressure. In the face of shrinking natural resources and ever-increasing demand for large food and agricultural production arising due to high population and income growths, agricultural intensification is the main course of future growth of agriculture. The ability of the country to diversity the cropping pattern for attaining various goals depends on the opportunities available for diversification, the need for diversification and responsibilities of the farmers to these needs and opportunities. The per capita availability of arable land in our country is quite low and declining over time. Diversification is the process to take advantage of emerging opportunities created by technology, new markets, changes in policy etc. to meet contain goals, challenges and threats and to reduce risk (Chand and Chauhan, 2002). Crop diversification is one of the major components of diversification in agriculture. Crop diversification can enable farmers to gain access to national and international markets with new products, food and medicinal plants. Diversification from the monoculture of traditional staples can have important nutritional benefits for public. Crop diversification may be adopted as a strategy for profit maximization through complimentary and supplementary relationships. It also acts as a powerful tool in minimization of risk in farming. These considerations make a strong case for farm/crop diversification in India (Gupta and Tewari, 1985). Crop diversification in India is considered as a shift from less profitable crop to more profit earning crops. Maximum remunerative profit and also the resilience or stability in production also induce crop diversification. Diversification and large number of crops are practised in dry areas to reduce crop failure due to drought. Crop replacement and shift are also taking place in problem soil areas. Diversification also occurs in some areas due to government policies and thrust in some crops over a given time. The main objectives of crop diversification is to include crops in the system for maximizing productivity, profitability under efficient use of resources in a location or region.

Need for Crop Diversification

Crop diversification helps in production of sufficient food grain in matching the agroecological conditions of the region. It also helps to earn sufficient cash for the producers for meeting the expenditure of cultivation and for the maintenance of the family. In brief diversification of crops must help to attain most sustainable agriculture. It helps to overcome the risk factor related to monocropping. It is important for offering more income and employment and keeps the environment safe.

Environmental factors/issues

Environmental factors include irrigation, rainfall, temperature, light interception and soil fertility. Excessive exploitation of underground water has led to fall in water table while excessive use of water in cannel network area brought about soil salinity and alkalinity. Continuous and heavy use of pesticides and agrochemicals in cereals crops has led to environmental hazards. Excessive use of chemical fertilizers has increased the nutrient concentration in water. Use of industrial effluents in agriculture creates heavy metal in agricultural products. However, while adopting crop diversification, farmers must ensure that it does not existing adversely affect the available natural resources.

Food and nutritional security

Per capita availability of food grains and vegetables are still below the normal recommended level. There is need to increase production of food grains and vegetables even the production of oilseeds and pulses. There is need for diversification within crops and which help maintain nutrition security for the farmers

Sustainability issues

Monocropping are commonly adopted cropping system have rendered number of disadvantages in farmers. Such practice in farming has tended to decreasing fertility and stability moreover decline in factor productivity. Pulses in cropping system in addition of organic matter supply also increase the enhancement of nitrogen fixation which ultimately improves soil fertility. Diversification through pulses not only replenishing the soil health but also economises upon input use favouring the cost of production.

Agricultural Biodiversity and insect pest management

Diversification provides scope for inclusion of various crops of distinct genetic- make up in cropping system. Pest control is an essential element in crop production. Diversification decreases the chance of occurrence of insect pest and diseases and weed problem.

Provides employment opportunities

In crop diversification a number of most remunerative crops are selected and grown in the year round. Even high value horticultural crops, including spices are taken for cultivation. This creates greater avenues for employment of farm employment throughout the year.

For aberrant weather conditions

In India since about 65% area is grown under rainfed conditions. These areas have higher risk of crop failure due to uncertain rainfall. Diversification through intercropping, agro-forestry, agri - horticultural system may help in minimizing the risk and raising the income of the farmers. For multiply food basket and buffer stock diversification aims at to grow a number of food crops to meet the dietary needs of the farmers. The substantial growth in the area of staple food crops coupled with productivity gain by virtue of high yielding varieties and improved production technology may result in huge food grains stock contrary to this the country has to consider the diversification for growing of edible oilseeds and pulses to meet the requirement.

Scope for Diversification

There are large number of prevailing conditions which are greatly helpful for encouraging diversification. Suitability of Agro-Climatic situation in India is bestowed with temperature to tropical climate which offer excellent scope for diversification of various types of crops.

Availability of appropriate technology

Appropriate technology suiting to pre-vailing agro-climatic conditions and local needs of people are available. Furthermore, directorate of agriculture of the state government with strong extension services are available for providing training and necessary instruction,

Remunerative avenues of diversification:

There are different avenues of diversification like diversification through Pulses and oilseeds, with fodder crops and horticultural crops. Diversification with medicinal and aromatic plants is also available.

Advantages of Diversification:

More income and poverty alleviations: -

About 76% of the total farming community belongs to marginal and small farmers. Crop diversification aims at to increase production of various types of crops and thereby to increase the income of the farming community. To overcome the problems of low food production and farmer's income, existing cropping pattern must be diversified with high value crops.

Improved soil health:

Monoculture is always harmful as it destroys soil fertility and stability. Intensive cropping also shows deteriorative effect on soil fertility. However, diversity of cropping having varied requirement of soil nutrients provides balanced nutrients. Diversification in cropping system can eliminate loss of fertility and stability and insect pest incidence.

Employment generation:

Through diversification more employment can be generated at the farm with increased activities throughout the years. The employment opportunities are increased with mixed farming of poultry, fish and goat with crop production. Integrating crop production along with dairying and sericulture enhance farmer's income and generate employment opportunities.

Mitigation of natural calamities:

Sudden adverse weather conditions like erratic rainfall, drought, frost hail, incidence of insect pest disease may be combated by diversification of crops and cropping systems. In this respect, diversification through mixed cropping and intercropping may be most feasible system of cropping.

Utilization of farm waste:

Effective recycling of farm resources is possible through diversification in crop production. Combination of cropping and poultry wherein crop by-products is used as cattle breed. Animal waste can also be used as source for production of bio-gas.

Conservation:

Crop diversification helps in conservation of natural resources like introduction of legume crops in cereal based cropping systems help in fixation of atmospheric nitrogen to sustain soil fertility and stability.

Diversification and globalization:

Expansion of area and enhancement of quality should be done for traditionally exported material. Special care should be taken for export of basmati rice, condiments, spices etc. In order to increase the opportunity of exports production as well as post-harvest activities of vegetables and tropical fruits are required which can be achieved by diversification of crop.

Approaches of crop diversification:

Horizontal diversification:

This approach aims at intensification of crop cultivation or adoption of cropping system with an object of increasing total production as well as total productivity of farm.

Vertical approach:

Vertical cropping refers to the system of cultivating crops in vertically stoked layer, instead of a single surface like a greenhouse or field. Vertical farming is a method of growing crops by artificially stocking plants vertically above each other either in skyscrapers or by using the wind dimension of space.

Crop substitution on replacement:

This refers to inclusion of less shiftable less profitable crops or cropping system with more suitable profitable crops or cropping system based upon the agro-climatic conditions of a specific location or region. In crop substitution high risk prone less profitable crops are substituted with better built in characters of crops having high yield potential.

Alley cropping:

It is planting of two or more sets of single or multiple rows of trees of shrubs at wide spacing creating alley ways within which agricultural, horticultural or forage crops are cultivated. Alley chopping diversifies farm enterprises by providing short-term cash flow from annual crops which also providing medium to long-term product from the threes. Alley cropping protects crops from insect pests by reducing crop visibility dilating pest hosts due to plant diversity.

Ley farming:

This is a rotation system in which a grass-legume mixture is grown in rotation with agricultural crops. The system is sometimes called “alternate husbandry” or mixed farming. The grass- legume mixture is called the ley. In such farming grasses, helps to improve structure of soil and legumes help to improve the soil nitrogen status (Jareski and Lal, 2003)

Agri-horticultural system:

In this form tree component is fruit trees. It is also called as food-cum- fruit system in which short duration arable coups are raised in the inter space of fruit trees. Pulses are the important arable crops for this system. Depending on the requirement other crops like sorghum and pearl millet can be grown in the interspace of fruit trees.

Diversification under marginal land:

Such type of lands have problems like poor drainage, sleep slope, poor soil depth and many other problems. Such type of land can be used for growing tree plants or can be developed for pasture.

Silvi-Pastural system:

This is an agro-forestry system involving integration of fruit trees with pasture with fruit trees is replaced by top feed trees, it is called silvi-pastural system.

Diversification under assured irrigation facilities:

Multiple cropping is most suitable in the area where moisture through irrigation is available throughout the year. Availability of moisture in soil throughout the year provides suitable conditions for sequential cropping. Furthermore, under assured irrigation number of crops can grown in multiple cropping system.

Crop diversification under water scare condition:

In rainfed condition rainfall does not follow any systematic pattern. Dry tracts are those which receive annually rainfall of 500mm or less. Even this much rain is not well distributed and due to that crop production become very poor. In crops very often suffered from aberrant weather. In such situation single of intercropping is feasible.

Diversification under high rainfall area:

A number of crops grown well under lowland conditions than cereals because high rainfall humidity affect the reproduction as well as chances of insect pest attack also increased upland rice with annual rainfall of 2000 mm for at least 5-6 months is suitable for such upland rice cultivation (De Datta, 1981).

Crop diversification as a strategy for Various national commitments:

Food and nutritional security and poverty-alleviation:

India has made impressive strides on the agriculture front during the last four decades. Increased agriculture productivity in the recent years has contributed to a significant reduction in poverty level from 35 percent 1973 to 26 Percent in 1998. With about 250 million below the poverty line India accounts for about one-fifth of the world's poor. Since independence not only has the production of food grain increased but also commercial crop production has also increased. Land resources are low, with the average holding size in Indian being only 1.57 ha during the 1990-91 census year (Hazra,2001). Under such condition the national agenda of the government is to increase production within short time. The main aim to increase the production for domestic need and to keep some product for export purpose.

Management of natural resources for development of Sustainable agriculture:

The declination in water and land resources are in the main causes of land degradation in Indian agriculture. There is greater need to have an integrated approach in the management of plant nutrients, chemicals and taking effective measures to deal with the overall pollution problem. Proper management of water and appropriate land may reduce the degradation of environment.

Agricultural planning: An area Approach

The Agro-Climatic Regional planning was a new approach that was put into action in 1988. This is a connection between the resource base and decentralize planning (Kashyap and Mathur, 1999). This holistic approach diagnoses from the sectoral approach of planning practiced so far in the country. It explicitly recognizes the local resource endowments and constraints of the agro- climatically homogenous regions, quite often cutting across the state.

Diversification in Indian Scenario:

About 70 percent of above I billion Indian population live in rural areas and their primary occupation id agriculture. Marginal and small farmers constitute about 80% cultivating only 29% of the consolidated and scattered arable land. Due to presence of different agro-climatic conditions in India huge quantity of agricultural product is being manufactured by the farmers. Crop diversification is expected to provide huge option to produce wide type of crops under a certain area. Crop diversification is used in the rainfed area to minimize the hazard related to crop failure because of less rain and drought (Reddy and Suresh,2009). Crop diversification is also used in the having several soil problems.

Government policies and strategies for diversification:

Taking into account the significance of crop diversification in Indian agriculture, the government has adopted several policies for the development of agriculture and especially for the development of crop diversification. National Agricultural Insurance scheme on food crops, oilseeds, annual commercial and horticultural crops come under the coverage of the scheme infrastructural support for developing horticulture as well as to emphasis on post-harvest management for the construction, modernization, expansion of cold storage and storage of horticultural crops government provides a capital subsidy of 25%. More attention should be paid to develop an efficient market for domestic purpose.

Conclusion:

To meet the challenges, the production strategy should be to encourage diversification of the production system without sacrificing the basic obligation of ensuring food security. Crop diversification is now instance to maintain the sustainability in agricultural production. It helps to increase the quality, quantity and earning from the production they secure the economic condition of farmer. Diversification of crops and cropping system can play a key role in overcoming any prevailing problem. Special attention given to small and marginal farmers so that direct advantages can reach to this portion of population.

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Effect of Intercropping and Fertility Levels on Pigeonpea (*Cajanas cajana*) Based Inter-Cropping System in Rainfed Upland of North Western Plateau Zone of Odisha

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Abstract

The investigation designed to study the "Effect of intercropping and fertility level on pigeonpea based intercropping sustain in rainfed upland of north central plateau zone of Odisha way conducted during rainy (*kharif*) season for two consecutive years 2017-18 and 2018-19 on mixed red and yellow lateritic soils of Krishi Vigyan Êendra, Sundergarh, Orissa University of Agriculture and Technology, Odisha. Growth, yield attributes, grain and dry stalk yields of pigeonpea and intercrops were affected significantly with fertility management/ practices. Pigeonpea planted at 100cm row distance along with two rows of greengram recorded plant height. However, pigeonpea planted at 75cm with one row of groundnut recorded maximum dry matter pen plants. An increase in level of fertility recorded higher magnitude of plant height and dry matter per plant. Pigeonpea at 50 and 75 cm intercropping with groundnut recorded appreciably higher yield, two rows of groundnut intercropping with 75cm spacing of pigeonpea recorded higher yield of intercropping. Graded level of fertility showed corresponding increase in yield of both maincrop and intercrop. All the intercropping system gave higher equivalent yield over sole cropping. Pigeonpea at 75 cm row distance intercropped with two rows of groundnut recorded higher equivalent yield of pigeonpea. Increase in fertility level recorded corresponding increase in equivalent yield. Pigeonpea at 75 cm with two rows of groundnut recorded maximum land equivalent ratio indicating better advantage. Increase in fertility rate also recorded higher land equivalent ratio. Aggressivity values of intercropping systems are greater than zero indicating yield advantage over sole cropping. Increase in level of fertility recorded higher aggressivity. The relative crowding coefficient and product of intercropping system indicate competitive relationship between pigeonpea planted at 75cm with two rows of groundnut indicating advantages pigeonpea at 75cm with one row of groundnut recorded maximum monetary advantage. Pigeonpea at 75 cm with two rows of groundnut recorded maximum net return and B:C ratio. Higher level of fertility followed the similar trend. The uptake of NPK is higher in intercrop stands over their pure stands. Organic carbon content in soil is recorded higher in intercropping stands.

Introduction

In rainfed upland situation of north western plateau region of Odisha, there is need of serious thought to replace or substitute traditional crops live a rice, maize with more sustainable suitable, remunerative erosion resisting, soil enrichment crop. Among rainy season crops, pigeonpea (*Cajanas cajana)* being a drought resistant, deep rooted, short days. Day neutral legume crop may be a good choice for its cultivation in rainfed upland conditions in north western plateau region of odisha. It is thought that pigeonpea with its inherent characters will be a suitable choice for its cultivation in rainfed uplands with light textured soil in plateau region in consideration of checking erosion and improvement of soil fertility and stability. Intercropping has been recognized as a potentially beneficial system of crop production and evidences indicate that it can provide sustainable yield advantages over sole cropping. (Tsubo *etal.* 2005). Intercropping not only provides certain insurance against biotic and environmental stress but also gives extra yield advantage by simple expedient of growing crops (Willey, 1979). Plant density and planting geometry of component crops play an important role in maximising the productivity of intercropping system (Srinivasan and Ahlawat, 1984). Similarly, fertilizer management is the important aspect of intercropping system, since the associated crops are different nature of growth and nutritional needs. Nutrient requirements of crops in intercropping system depend on nature of component crops, spatial arrangement in a system. The kind of intercrops and spatial arrangement in intercropping have important effects on the balance of competition between component crops, productivity, nutrient uptake and soil fertility status. Keeping in view these aspects, thine is a dine need to study the effect of intercropping and fertility level on pigeonpea based intercropping system in rainfed upland of north western plateau region of Odisha.

Materials and Methods

A field experiment was conducted during the rainy (*kharif*) season of 2017-18 and 2018-19 at the Instructional Farm of Krishi Vigyan Kendra, Sundargarch, Orissa University of Agriculture and Technology, Odisha, $20^{0}35'$-$22^{0}32'$N Latitude $83^{0}32'$-

TABLE 1. Effect on plant height and dry matter accumulation of Pigeonpea in intercropping system and Nutrient management

Treatments	Plant height (cm)			Dry matter(g/plant)		
A. Cropping system	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**
Sole pigeonpea at 50 cm	174.2	174.8	174.5	355.2	356.5	355.9
Pigeonpea at 50 cm+ 1 row of greengram (1:1)	166.5	170.4	168.45	348.2	352.4	350.3
Pigeonpea at 75 cm+ 1 row of greengram (1:1)	168.2	172.8	170.5	358.4	362.5	360.5
Pigeonpea at 75 cm+ 2 rows of greengram (1:2)	167.6	168.4	168	355.6	360.8	358.2
Pigeonpea at 100 cm + 2 rows of greengram (1:2)	173.2	177.5	175.35	361.8	362.4	362.1
Pigeonpea at 100 cm+ 3 rows of greengram (1:3)	172.3	171.9	172.1	359.1	359.8	359.5
Pigeonpea at SO cm + 1 row of groundnut (1:1)	169.4	170.8	170.1	352.6	354.2	353.4
Pigeonpea at 75 cm + 1 row of groundnut (1:1)	171.6	172.8	172.2	361	363.4	362.2
Pigeonpea at 75 cm + 2 rows of groundnut (1:2)	168.2	169.6	168.9	360.5	359.8	360.2
Pigeonpea at 100 cm + 2 rows of groundnut (1:2)	174.4	174.1	174.25	364.8	365.6	365.2
Pigeonpea at 100 cm + 3 rows of groundnut (1:3)	170.6	169.2	169.9	362.7	364.1	363.4
SEm (±)	0.65	0.68	0.67	1.60	0.61	1.10
CD at0.05%	1.39	1.47	1.43	3.43	1.31	2.37
B. Fertility level (N, P2Os, K2O kg/ha)						
Control	164.0	163.3	163.7	352.1	353.8	353.0
20:30:20	167.4	169.0	168.2	356.4	357.8	357.1
20:60:40	173.8	175.0	174.4	360.0	362.4	361.2
40:80:60	176.8	181.0	178.9	364.8	366.0	365.4
SEm (±)	0.85	0.79	0.82	1.38	2.81	1.66
CD at0.05%	1.81	1.72	1.77	4.26	3.9	3.18

$85^0$22'E longitude and at an altitude of 259 meters above mean sea level. The Experiment way conducted on sandy clay loam soil, having pH 5.7, organic carbon 0.58%, available N 265 kg/ha, available P 15.0 kg/ha and available K 140 kg/ha. The experiment was laid out in split-plot design with cropping systems in main plot and fertility management in a sub plot using three replications. The experiment consisted of 13 cropping systems i.e (i) Sole pigeonpea at 50 cm, (ii) Sole greengram at 25 cm, (iii) Sole groundnut at 25 cm, (iv) Pigeonpea at 50 cm + 1 row of greengram (1:1), (v) Pigeonpea at 75 cm + 1 row of greengram (1:1), (vi) Pigeonpea at 75 cm + 2 rows of greengram (1:2), (vii) Pigeonpea at 100 cm + 2 rows of greengram (1:2), (viii) Pigeonpea at 100 cm + 3 rows of greengram (1:3), (ix) Pigeonpea at 50 cm + 1 row of groundnut (1:1), (x) Pigeonpea at 75 cm + 1 row of groundnut (1:1), (xi) Pigeonpea at 75 cm + 2 rows of groundnut (1:2), (xii) Pigeonpea at 100 cm + 2 rows of groundnut (1:2), (xiii) Pigeonpea at 100 cm + 3 rows of groundnut (1:3) in main plots and 4 fertility management comprising of combination of 4 nutrient management practices i.e. (i)Control, (ii)20 kg N + 30 kg P, O… + 20 kg K, O, (iii)20 kg N + 60 kg P, O… + 40 kg K, O, (iv)40 kg N + 80 kg P, O… + 60 kg K, O in sub plots. Pigeonpea: "UPAS 120", Greengram:" TARM-1" Blackgram: "PU-35" Groundnut: "Devi" were sown on 4th and 5th July during 1st and 2nd year respectively. Entire dose of N, P, O… and K, O were incorporated in soil, as per the treatments. Two weeding were done for weed management 25 and 75 days after sowing during both the years. There was uniform distribution of rainfall from July to November during both the years. Rainfall received during crop period of 2017-18 and 2018-19 was 1061.4 and 1298.3 mm respectively. Pigeonpea was harvested by November 5, 2018 and November 7, 2019 during the growing season respectively. Greengram harvested by 28th August and 5th September in corresponding years whereas groundnut was harvested on 22 August in first year and on 25th August in second year respectively. Competition functions were computed as per Willey (1979). Pigeonpea equivalent was calculated on the basis of market price of greengram and groundnut.

Results and Discussion

Growth parameters of maincrop and intercrops: In general, sole crop of pigeonpea exhibited higher plant height except in intercrop stand of pigeonpea spaced at 100cm with 2 rows of greengram. Increased plant height in sole crop of pigeonpea might be due to the absence of interspecific competition and limited disturbance of habitat. Intercropped pigeonpea at row spacing of 100 cm along with 2 rows of greengram also registered higher plant heights similarly to that of sole pigeonpea. Such increase in plant height is ascribed to vigorous and enhanced plant growth of pigeonpea in wide row spacing as a result of reduced inter-row specific competition for natural resources. The results are in conformity with the findings of kumar *et al.* (2003). The height of pigeonpea under intercropping decrease appreciably and significantly compared with sole cropping because of more inter-specific competition than intra-specific competition on of sole stand. Padhi *et al.*, (1992) also reported similar results. Maximum plant height of pigeonpea by obtained under the highest level of NPK at 40 kg N + 80 kg P, O… + 60 kg K, O is largely a function of improved growth of the crop an account of balanced nutrition. The higher dry matter production per plant of widely spaced crop of pigeonpea might be due to competition free environment under this system of intercropping. There was no adverse effect of greengram and groundnut intercropping on the growth of principal crop of pigeonpea planted at wider spacing. Bain's and Choudhury (1971) also reported the same. Increased rate of fertility significantly enhanced the dry matter of pigeonpea which might be resulted from favourable influence of balanced nutrition on the growth components leading to higher dry matter accumulation in pigeonpea plant (Kujur *et al*, 2010).

Yield attributes and yield of maincrop and intercrop, in most of the intercropping systems, the number of Pods/Plant in pigeonpea significantly decreased as compared with sole crop. The cropping system could not be able to exert marked that on yield parameters of pigeonpea. The increase in number of pods/leant with application of increased rate of fertility is largely function of improved growth and

Table 2. Effect on yield attributing character of Pigeonpea in intercropping system and Nutrient management

Treatments	No of Pods/ Plant			No of Grains/Plant			Test Weight		
A. Cropping system	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**
Sole PP 50 cm	142.5	143.5	143	3.8	5	4.4	74.6	75.9	75.25
PP 50+ 1 GG (1:1)	138.6	139.4	139	3.7	4.5	4.1	74.7	74.9	74.8
PP 75+ 1 GG (1:1)	141.6	138.4	140	3.8	4.8	4.3	74.6	74.5	74.55
PP 75+ 2 GG (1:2)	140.8	142.2	141.5	4.2	4.58	4.39	75.8	75.55	75.68
PP 100+ 2 GG (1:2)	141.7	142.7	142.2	4.22	4.58	4.4	76.4	76.3	76.35
PP 100+ 3 GG (1:3)	142.4	143.6	143	4.32	5.28	4.8	75.5	75.45	75.48
PP 50+ 1 GN (1:1)	141.4	140.6	141	3.65	4.35	4	75.4	75.6	75.5
PP 75+ 1 GN (1:1)	142.3	141.3	141.8	3.55	4.85	4.2	74.6	74.4	74.5
PP 75+ 2 GN (1:2)	142.8	142.4	142.6	3.97	4.63	4.3	76.2	76.5	76.35
PP 100+ 2 GN (1:2)	142.8	144	143.4	4.26	4.74	4.5	73.8	73.95	73.88
PP 100+ 3 GN(1:3)	143.2	145.2	144.2	4.8	4.74	4.77	76.5	76.4	76.45
SEm (±)CD at0.05%	1.08	1.66	1.46	0.03	0.04	0.04	0.57	0.48	0.62
	3.33	2.82	3.12	NS	NS	NS	NS	NS	NS
B. Fertility level (N, P_20_5, K_20 kg/ha)									
Control	139.4	138.8	139.1	4.1	3.9	4	71.2	73.3	72.2
20:30:20	141.8	140.4	141.1	4.3	4.1	4.2	71.2	75.3	73.2
0.875463	142	143.8	142.9	4.3	4.7	4.5	77.2	76.5	76.8
40:80:60	143.6	146.2	144.9	4.5	5.1	4.8	77.6	80.5	79
SEm (±)CD at0.05%	0.53	0.62	0.58	0.05	0.68	0.09	0.26	0.54	0.24
	1.64	1.88	1.86	NS	NS	NS	NS	NS	NS

Table 3. Effect on main crop and intercrop yield and pigeonpea equivalent Yield in intercropping system and Nutrient management

Treatments	Main crop yield(t/ha)			Intercrop yield(t/ha)			PYE yield(t/ha)			LER		
A Cropping system	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Sole PP 50cm	1.18	1.37	1.28				1.18	1.37	1.27	1	1	1
Sole GG 25 cm	0.76	0.84	0.80				0.83	0.92	0.88	1	1	1
Sole Gn 25 cm	1.02	1.34	1.18				0.86	1.13	1.00	1	1	1
PP 50+ 1 GG (1:1)	1.08	1.06	1.07	0.37	0.40	0.38	1.49	1.49	1.49	1.39	1.27	1.32
PP 75+ 1 GG (1:1)	1.04	1.06	1.05	0.34	0.34	0.34	1.41	1.43	1.42	1.32	1.21	1.25
PP 75+ 2 GG (1:2)	1.07	1.05	1.06	0.42	0.42	0.42	1.53	1.51	1.52	1.44	1.30	1.36
PP 100+ 2 GG (1:2)	0.9	0.89	0.90	0.39	0.42	0.40	1.33	1.34	1.34	1.26	1.17	1.21
PP 100+ 3 GG (1:3)	0.89	0.9	0.90	0.46	0.48	0.47	1.39	1.43	1.41	1.34	1.27	1.29
PP 50+ 1 GN (1:1)	1.11	1.14	1.13	0.46	0.50	0.48	1.50	1.56	1.53	1.34	1.26	1.28
PP 75+ 1 GN (1:1)	1.12	1.16	1.14	0.52	0.55	0.53	1.56	1.62	1.59	1.40	1.31	1.34
PP 75+ 2 GN (1:2)	1.16	1.17	1.17	0.58	0.62	0.60	1.66	1.68	1.67	1.50	1.37	1.42
PP 100+ 2 GN (1:2)	1.02	1.05	1.04	0.57	0.61	0.59	1.50	1.57	1.53	1.36	1.29	1.31
PP 100+ 3 GN(l:3)	1.01	1.04	1.03	0.60	0.65	0.63	1.52	1.59	1.55	1.38	1.32	1.33
SEm (±)	0.08	0.04	0.06	0.03	0.04	0.03	0.02	0.02	0.03	0.09	0.06	0.09
CD at0.05%	0.24	0.04	0.14	0.14	0.11	0.13	0.05	0.06	0.08	0.28	0.19	0.32
B. Fertility level (N, P_20_5, K_20 kg/ha)												
Control	0.92	1.05	0.99	0.36	0.41	0.39	1.27	1.39	1.34	1.28	1.18	1.23
20:30:20	1.13	1.2	1.17	0.47	0.5	0.49	1.54	1.64	1.60	1.56	1.39	1.47
20:60:40	1.29	1.42	1.36	0.49	0.59	0.54	1.75	1.89	1.83	1.77	1.60	1.68
40:80:60	1.4	1.42	1.41	0.6	0.62	0.61	1.89	1.94	1.92	1.91	1.64	1.76
SEm (±)	0.045	0.051	0.08	0.019	0.018	0.018	0.063	0.065	0.066	0.07	0.054	0.06
CD at0.05%	0.13	0.11	0.18	0.5	0.4	0.5	0.19	0.21	0.18	0.24	0.15	0.19

Table 4. Effect on Yield, Biological yield and Harvest Index of pigeonpea in intercropping system and Nutrient management

Treatments	Grain Yield (t/ha)			Stalk yield (t/ha)			Biological yield (t/ha)			Harvest index (%)		
A Cropping system	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Sole PP SO cm	1.2	1.4	1.3	5.4	5.3	5.3	6.6	6.7	6.6	18.0	20.6	19.3
PP 50+ 1 GG (1:1)	1.1	1.1	1.1	4.6	4.8	4.7	5.7	5.9	5.8	19.1	18.1	18.6
PP 75+ 1 GG (1:1)	1.0	1.1	1.1	4.3	4.6	4.5	5.4	5.6	5.5	19.3	18.8	19.1
PP 75+ 2 GG (1:2)	1.1	1.1	1.1	4.6	4.7	4.7	5.7	5.7	5.7	18.8	18.3	18.6
PP 100+ 2 GG (1:2)	0.9	0.9	0.9	3.9	4.1	4.0	4.8	5.0	4.9	18.9	17.8	18.3
PP 100+ 3 GG (1:3)	0.9	0.9	0.9	3.8	3.9	3.8	4.7	4.8	4.7	18.9	19.0	18.9
PP 50+ 1 GN (1:1)	1.1	1.1	1.1	4.6	4.7	4.6	5.7	5.8	5.8	19.6	19.6	19.6
PP 75+ 1 GN (1:1)	1.1	1.2	1.1	4.7	4.5	4.6	5.8	5.7	5.7	19.3	20.5	19.9
PP 75+ 2 GN (1:2)	1.2	1.2	1.2	4.6	4.7	4.6	5.8	5.8	5.8	20.4	19.9	20.1
PP 100+ 2 GN (1:2)	1.0	1.1	1.0	4.3	4.2	4.3	5.3	5.3	5.3	19.3	19.9	19.6
PP 100+ 3 GN(l:3)	1.0	1.0	1.0	4.2	4.3	4.3	5.2	5.4	5.3	19.3	19.4	19.4
SEm (±)	0.08	0.04	0.08	0.34	0.31	0.34	0.42	0.4	0.4	0.46	0.52	0.5
CD at 0.05%	0.24	0.41	0.11	1.05	1.14	1.12	1.3	1.15	1.18	NS	NS	NS
B. Fertility level (N, P_20_5, K_20 kg/ha)												
Control	0.8	0.9	0.8	4.1	4.4	4.2	4.9	5.3	5.1	16.2	17.3	16.8
20:30:20	1.0	1.0	1.0	4.3	4.6	4.4	5.2	5.6	5.4	18.6	18.6	18.6
20:60:40	1.1	1.3	1.2	4.5	5.2	4.8	5.6	6.4	6.0	20.0	19.7	19.8
40:80:60	1.2	1.3	1.3	4.3	4.5	4.4	5.5	5.8	5.7	22.0	21.4	21.7
SEm (±)	0.05	0.04	0.04	0.19	0.21	0.24	0.24	0.23	0.24	0.20	0.40	0.60
CD at 0.05%	0.41	0.43	0.42	0.60	0.69	0.70	0.74	0.80	0.79	NS	NS	NS

TABLE 5. Effect on Land Equivalent Ratio (LER) in intercropping system and Nutrient management

Treatments	2017-18			2018-19			Pooled		
A Cropping system	LER of Main Crop	LER of Intercrop	Total LER Intercrop	LER of Main Crop	LER of Intercrop	Total LER	LER of Main Crop	LERof Intercrop	Total LER
PP 50+ 1 GG (1:1)	0.92	0.47	1.39	0.77	0.50	1.27	0.84	0.48	1.32
PP 75+ 1 GG (1:1)	0.88	0.44	1.32	0.77	0.44	1.21	0.82	0.43	1.25
PP 75+ 2 GG (1:2)	0.91	0.53	1.44	0.77	0.53	1.3	0.83	0.53	1.36
PP 100+ 2 GG (1:2)	0.76	0.50	1.26	0.65	0.52	1.17	0.70	0.51	1.21
PP 100+ 3 GG (1:3)	0.75	0.59	1.34	0.66	0.61	1.27	0.70	0.59	1.29
PP 50+ 1 GN (1:1)	0.94	0.40	1.34	0.83	0.43	1.26	0.88	0.40	1.28
PP 75+ 1 GN (1:1)	0.95	0.45	1.4	0.85	0.46	1.31	0.89	0.45	1.34
PP 75+ 2 GN (1:2)	0.99	0.51	1.5	0.85	0.52	1.37	0.91	0.51	1.42
PP 100+ 2 GN (1:2)	0.86	0.50	1.36	0.77	0.52	1.29	0.81	0.50	1.31
PP 100+ 3 GN(l:3)	0.86	0.52	1.38	0.76	0.56	1.32	0.80	0.53	1.33
SEm (±)CD at0.05%			0.09			0.06			0.09
			0.28			0.19			0.32
B. Fertility level (N, P_20_5, K_20 kg/ha)									
Control	0.78	0.50	1.28	0.77	0.41	1.18	0.77	0.46	1.23
20:30:20	0.96	0.60	1.56	0.88	0.51	1.39	0.91	0.56	1.47
20:60:40	1.09	0.68	1.77	1.04	0.56	1.6	1.06	0.62	1.68
40:80:60	1.19	0.72	1.91	1.04	0.60	1.64	1.10	0.66	1.76
SEm (±)			0.07			0.054			0.06
CD at0.05%			0.24			0.15			0.19

Table 6. Effect on Relative Crowding Co-efficient (RCC) in intercropping system and Nutrient management

Treatments	2017-18			2018-19			Pooled		
A Cropping system	RCC of Main Crop	RCC of intercrop	Product Value (K)	RCC of Main Crop	RCC of intercrop	Product Value (K)	RCC of Main	RCC of intercrop	Product Value (K)
PP 50+ 1 GG (1:1)	10.80	0.86	9.29	3.42	1.00	3.42	5.10	0.91	4.62
PP 75+ 1 GG (1:1)	7.43	0.74	5.49	3.42	0.74	2.53	4.57	0.74	3.38
PP 75+ 2 GG (1:2)	19.45	0.55	10.76	6.56	0.55	3.63	9.64	0.55	5.33
PP 100+ 2 GG (1:2)	6.43	0.48	3.06	3.71	0.55	2.05	4.74	0.50	2.37
PP 100+ 3 GG (1:3)	9.21	0.45	4.15	5.74	0.50	2.87	7.11	0.48	3.38
PP 50+ 1 GN (1:1)	15.86	0.64	10.13	4.96	0.74	3.65	7.53	0.69	5.17
PP 75+ 1 GN (1:1)	18.67	0.79	14.71	5.52	0.87	4.82	8.14	0.82	6.63
PP 75+ 2 GN (1:2)	76.67	0.48	37.03	11.05	0.55	6.12	21.27	0.52	11.00
PP 100+ 2 GN (1:2)	12.75	0.47	5.95	6.56	0.54	3.51	8.67	0.50	4.34
PP 100+ 3 GN(l:3)	17.82	0.35	6.15	9.45	0.41	3.87	12.36	0.38	4.72
B. Fertility level (N, P_20_5, K_20 kg/ha)									
Control	37.87	1.09	41.19	22.01	1.25	27.47	17.90	1.17	20.88
20:30:20	46.51	1.42	66.04	25.16	1.52	38.28	21.15	1.47	31.00
20:60:40	53.09	1.48	78.60	29.77	1.80	53.45	24.59	1.62	39.71
40:80:60	57.62	1.81	104.46	29.77	1.89	56.17	25.49	1.82	46.51

Table 7. Effect on Gross cost, Net return and BC ratio in Pigeonpea based intercropping system

Treatments A Cropping system	2017-18 Gross Cost	Gross returns	Net returns (x1<tRs /ha)	BC ratio	2018-19 Gross Cost (x1<tRs /ha)	Gross returns (x1<tRs /ha)	Net returns (x1<tRs /ha)	BC ratio	Pooled Gross Cost (x1<tRs/ha)	Gross returns (x1<tRs /ha)	Net returns (x1<tRs /ha)	BC ratio
Sole PP 50 cm	18.5	37.8	19.3	2.04	18.5	43.8	25.3	2.37	18.5	40.8	22.3	2.21
SoleGG 25cm	15.4	26.6	11.2	1.73	15.4	29.4	14.0	1.91	15.4	28.0	12.6	1.82
Sole Gn 25 cm	15.4	27.5	12.1	1.79	15.4	36.2	20.8	2.35	15.4	31.9	16.5	2.07
PP 50+ 1 GG (1:1)	18.8	47.5	28.7	2.53	18.8	47.7	28.9	2.54	18.8	47.6	28.8	2.53
PP 75+ 1 GG (1:1)	18.5	45.2	26.7	2.44	18.5	45.9	27.4	2.48	18.5	45.6	27.1	2.46
PP 75+ 2 GG (1:2)	18.6	48.9	30.3	2.63	18.6	48.4	29.8	2.60	18.6	48.7	30.1	2.62
PP 100+ 2 GG (1:2)	18.4	42.5	24.1	2.31	18.4	43.0	24.6	2.34	18.4	42.8	24.4	2.32
PP 100+ 3 GG (1:3)	18.8	44.5	25.7	2.37	18.8	45.7	26.9	2.43	18.8	45.1	26.3	2.40
PP 50+ 1 GN (1:1)	19.1	47.8	28.7	2.50	19.1	49.8	30.7	2.61	19.1	48.8	29.7	2.56
PP 75+ 1 GN (1:1)	19.0	49.9	30.9	2.63	19.0	51.8	32.8	2.73	19.0	50.9	31.9	2.68
PP 75+ 2 GN (1:2)	19.5	53.1	33.6	2.72	19.5	53.7	34.2	2.76	19.5	53.4	33.9	2.74
PP 100+ 2 GN (1:2)	19.0	47.9	28.9	2.52	19.0	50.1	31.1	2.64	19.0	49.0	30.0	2.58
PP 100+ 3 GN(l:3)	20.0	48.5	28.5	2.42	20.0	50.9	30.9	2.54	20.0	49.7	29.7	2.48
SEm (±)	0.7	2.4	1.8	0.06	0.4	2.8	1.2	0.03	0.6	2.1	1.5	0.05
CD at0.05%	1.9	7.9	5.8	0.19	1.5	7.5	5.0	0.11	1.9	7.1	5.1	0.18
B. Fertility level (N, P_20_5, K_20 kg/ha)												
Control	18.0	40.6	22.6	2.26	18.0	46.3	28.3	2.57	18.0	43.6	25.6	2.42
20:30:20	20.5	50.7	30.2	2.47	20.5	53.9	33.4	2.63	20.5	52.5	32.0	2.56
20:60:40	21.4	56.5	35.1	2.64	21.4	63.7	42.3	2.98	21.4	60.1	38.7	2.81
40:80:60	23.8	63.4	39.6	2.66	23.8	64.7	40.9	2.72	23.8	64.0	40.2	2.69
SEm (±)	0.4	1.6	1.16	0.07	0.4	1.6	1.16	0.04	0.4	1.6	1.16	0.04
CD at0.05%	1.1	4.5	3.40	0.22	1.1	4.5	3.40	0.14	1.1	4.5	3.40	0.12

Table 8. Effect on nutrients status in intercrop treatments based on dry matter accumulation after harvest

Treatments A. Cropping system	N Uptake Main Crop 2017-18	N Uptake Main Crop 2018-19	N Uptake Main Crop Pooled	N Uptake Inter-crop 2017-18	N Uptake Inter-crop 2018-19	N Uptake Inter-crop Pooled	P Uptake Main Crop 2017-18	P Uptake Main Crop 2018-19	P Uptake Main Crop Pooled	P Uptake Inter-crop 2017-18	P Uptake Inter-crop 2018-19	P Uptake Inter-crop Pooled	K Uptake Main Crop 2017-18	K Uptake Main Crop 2018-19	K Uptake Main Crop Pooled	K Uptake Inter-crop 2017-18	K Uptake Inter-crop 2018-19	K Uptake Inter-crop Poo-led
Sole PP 50 cm	55.2	57.7	56.5		20.3	21.1	20.7		74.2	71.7	72.95							
SoleGG 25cm	48.5	49.6	49.1		16.5	18.3	17.4		64.2	66.4	65.3							
Sole Gn 25 cm	50.6	50.1	50.4		17.6	18.5	18.1		67.4	65.9	66.65							
PP 50+ 1 GG {1:1)	54.9	56.8	55.9	13.4	12.9	13.2	18.7	20.2	19.5	7.5	8.9	8.2	74.3	76.1	75.2	15.4	18.4	16.9
PP 75+ 1 GG (1:1)	56.6	57.4	57.0	14.2	15.9	15.1	20.1	20.8	20.5	8.2	9.9	9.1	75.8	78.5	77.2	18.4	20.5	19.5
PP 75+ 2 GG {1:2)	58.3	60.2	59.3	14.8	17.4	16.1	20.9	21.6	21.3	10.4	12.2	11.3	74.8	77.2	76.0	23.1	21.5	22.3
PP 100+ 2 GG (1:2)	60.5	61.8	61.2	17.2	19.4	18.3	22.8	24.1	23.5	10.5	13.8	12.2	77.5	79.1	78.3	25.1	23.4	24.3
PP 100+ 3 GG {1:3)	62.3	64.1	63.2	18.4	19.8	19.1	25.8	21.9	23.9	10.9	15.2	13.1	78.2	81.6	79.9	17.6	19.3	18.4
PP 50+ 1 GN (1:1)	56.6	58.4	57.5	13.8	14.7	14.3	17.8	22.4	20.1	7.8	10.5	9.2	82.6	84.1	83.4	18.5	20.4	19.5
PP 75+ 1 GN {1:1)	58.5	60.2	59.4	13.8	16.7	15.3	17.8	23.3	20.6	8.4	10.9	9.7	79.2	78.7	79.0	20.6	21.8	21.2
PP 75+ 2 GN (1:2)	59.7	61.9	60.8	15.9	18.2	17.1	20.5	24.1	22.3	10.4	12.8	11.6	78.4	80.1	79.3	22.1	24.3	23.2
PP 100+ 2 GN {1:2)	62.4	64.4	63.4	18.7	19.6	19.2	22.8	25.8	24.3	11.2	14.5	12.9	81.6	80.8	81.2	24.5	27.1	25.8
PP 100+ 3 GN{l:3)	65.2	65.4	65.3	19.5	20.8	20.2	23.7	26.8	25.3	14.6	17.2	15.9	82.8	84.5	83.7	27.5	28.9	28.2
SEm (±)	0.50	0.48	0.58	0.12	0.18	0.25	0.18	0.12	0.28	0.09	0.11	0.08	0.66	0.74	0.81	0.15	0.18	0.20
CD at 0.05%	1.56	1.42	1.67	0.36	0.42	0.38	0.57	0.63	0.72	0.25	0.27	0.25	2.06	2.14	2.52	0.48	0.56	0.65
B. Fertility level (N, $P_2 0_5$, $K_2 0$ kg/ha)																		
Control	54.5	55.8	55.2		17.8	20.5	19.2		75.2	73.8	74.5							
20:30:20	58.2	60.4	59.3		22.2	20.5	21.4		72.5	74.2	73.4							
20:60:40	60.5	61.8	61.2		23.5	22.4	23.0		75.2	74.9	75.1							
40:80:60	62.8	63.4	63.1		26.2	24.8	25.5		77.8	76.5	77.2							
SEm (±)	0.65	0.95	0.8		0.08	0.09	0.09		0.28	0.29	0.28							
CD at0.05%	1.42	2.02	1.72		0.26	0.34	0.48		0.87	0.92	0.88							

Table 9. Effect on organic carbon and Nutrients status in intercrop treatments of the experiment

Treatments	O C			N			p			K		
A Croppingsystem	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Sole PP 50 cm	0.45	0.44	0.45	221.5	228.8	225.2	18.4	20.2	19.3	223.5	226.8	225.15
Sole GG 25 cm	0.42	0.44	0.43	220.2	219.7	220.0	17.6	16.5	17.05	221.3	219.6	220.45
Sole Gn 25 cm	0.43	0.41	0.42	222.5	221.3	221.9	16.8	19.3	18.05	220.4	222.5	221.45
PP 50+ 1 GG (1:1)	0.44	0.48	0.46	227.2	228.9	228.1	18.4	19.8	19.1	226.2	225.7	225.95
PP 75+ 1 GG (1:1)	0.46	0.49	0.48	231.2	230.9	231.1	18.8	21.6	20.2	227.1	229.6	228.35
PP 75+ 2 GG (1:2)	0.51	0.5	0.51	231.6	235.2	233.4	20.5	22	21.25	229.1	231.5	230.3
PP 100+ 2 GG (1:2)	0.51	0.53	0.52	234.6	238	236.3	22.3	21.8	22.05	230.8	233.1	231.95
PP 100+ 3 GG (1:3)	0.54	0.53	0.54	238.2	240.5	239.4	22.5	24.6	23.55	234.2	233.9	234.05
PP 50+ 1 GN (1:1)	0.45	0.46	0.46	229.5	231.2	230.4	21.8	24.7	23.25	226.3	228.1	227.2
PP 75+ 1 GN (1:1)	0.48	0.47	0.48	231.5	234.8	233.2	24.6	23.8	24.2	227.3	229.3	228.3
PP 75+ 2 GN (1:2)	0.51	0.53	0.52	235.6	234.2	234.9	25.2	23.6	24.4	229.6	230.2	229.9
PP 100+ 2 GN (1:2)	0.55	0.53	0.54	238.1	239.6	238.9	24.7	26.1	25.4	231.5	234.6	233.05
PP 100+ 3 GN(l:3)	0.54	0.54	0.54	241.2	240.5	240.9	24.9	27.2	26.05	236.8	235.4	236.1
SEm(±)	0.004	0.004	0.004	2.01	2.06	2.94	0.02	0.02	0.02	1.98	1.84	1.78
CD at0.05%	NS	NS	NS	6.20	5.31	8.69	NS	NS	NS	NS	NS	NS
B. Fertility level (N, P_20_5, K_20 kg/ha)												
Control	0.45	0.47	0.46	223.6	222.8	223.2	19.9	19.1	19.5	224	226.8	225.4
20:30:20	0.46	0.5	0.48	224.4	226.4	225.4	20.7	22.1	21.4	224.8	232.4	228.6
20:60:40	0.46	0.52	0.49	226.4	228.6	227.5	21.6	23.4	22.5	229.4	234.2	231.8
40:80:60	0.5	0.52	0.51	224.4	235.8	230.1	24.3	25.3	24.8	233.1	236.1	234.6
SEm (±)	0.004	0.004	0.005	0.22	0.32	0.38	0.02	0.03	0.03	0.07	0.08	0.07
CD at0.05%	NS	NS	NS	0.64	0.86	0.97	NS	NS	NS	NS	NS	NS

corresponding development of yield attributes (Maitra *et al.*2001). Pigeonpea planted at wide row space with 3 rows of groundnut increased number of grains/pods marginally because of lesser depressing effect on wide spaced main crop.

Mixed stand of pigeonpea showed highest test weight of grains probably due to complementary effect between crop species. Pigeonpea planted of wider spacing gave higher test weight of grains owing to wider spacing of main crop experiencing less competition between species of crops. Increased fertility rate exhibited maximum test weight due to increased availability of nutrients through balanced fertilization (Kumar and Rana, 2007).

The grain yield of pigeonpea was appreciably higher sole cropping due to absence of competition and limited distribution to the habitat. Intercropping showed reduction in yield of pigeonpea ranging from 8.6 to 29.7% depending on nature of intercrop and spatial arrangement of base crop. Mixture yield of pigeonpea decreased with increase in row spacing. The lowest grain yield was found in widely spaced crop of pigeonpea probably due to lesser number of plants per unit area. Planting of pigeonpea at wider row spacing of 100 cm with 1 or 2 rows of greengram gave lowest yield due to lower plant density. Appreciable increase in grain yield of pigeonpea with increasing levels of fertility could be attributed to increased dry matter accumulation and dry matter partitioning and indirectly higher nutrient uptake by the crop. The yields of both the intercrop reduced considerably due to intercropping with pigeonpea. Such reduction varied from 46.6 to 57.5% depending on spatial arrangement of base crop and intercrop. Maximum reduction 57.5% in yield of greengram was noted in pigeonpea at 75cm with 1 or 2 rows of greengram probably due to more shading effect of closed row planted pigeonpea and at the same time lowest planting density of intercrop. Increasing fertility rate increased the yields of intercrops due to improvement in plant vigour and production of sufficient photosynthates owing to higher availability of nutrients resulting in better manifestation of yield attributes and finally higher grain yield.

Pigeonpea equivalent yield:

All the intercropping systems showed superiority to sole pigeonpea in terms of pigeonpea equivalent yield which was mainly due to additional advantage of intercrop yield and higher economic value of intercrops with pigeonpea. Yield advantage might have been owing to better utilization of solar radiation by combined crop canopy and of moisture and nutrients by combined root system (Snaydon and Hans, 1979). The differential behaviour in equivalent yield is on productivity of crops in intercropping system and their relative market prices. Significant increase in pigeonpea equivalent yield because of increased level of fertility to main crop and intercrops appears to be the results of higher productivity of both pigeonpea and intercrops with increasing levels of fertilizers (Jat and Gaur, 2000)

Dry stalk, Biological yield and Harvest index:

Sole crop of pigeonpea recorded higher magnitude of dry stalk and biological yields which were possibly due to enhanced growth and yield under competition free environment in habitat. Increased fertility rates improved both dry stalk and biological yield by supplying optimum rate of NPK nutrients. The depression of harvest index in narrower and wider now spacing of pigeonpea probably due to efficient growth of pigeonpea in combination with intercropping is an effect of heavy vegetation growth on light relationship with canopy (Donald and Hamblin, 1976). Increased rate of NPK exhibited a trend of increased harvest index which could be ascribed to more carbon assimilation and effective translocation of assimilate to reproductive parts.

Competition functions:

Intercropping of pigeonpea with greengram and groundnut irrespective of planting pattern and row ratios resulted in LER more than 1, indicating in yield advantages. The LER in intercropping systems varied from 1.21 to 1.42 which might be due to combined effect of natural and input resources.

The maximum total LER was recorded with the highest level for fertility in all the inter- cropping systems relative crowding coefficient (RCC) values recorded more than I showing better land utilization with higher & plant population than their sole crops. Increase in fertility levels from lower to higher markedly enhanced the product value (K). The maximum relative crowding coefficient (RCC) values were recorded with higher level of fertility.

The aggressive index indicated that pigeonpea with positive aggressivity proved to be more competitive than intercrops aggressivity of pigeonpea in intercropping system enhanced markedly with increased level of fertility. Intercropping of pigeonpea at 75 cm row along with I row groundnut gave lower values of competitive ratio indicating balanced competition between the two specifies signifying greater feasibility of the system. It indicated that higher level of fertility utilized the land more efficiently but it faced more crowd and competition among the component crops in the system.

Monetary Advantages:

Sole crop of pigeonpea resulted in maximum monetary value possibly due to higher economic value obtained from natural habitat of the crop without inter specific competition. Pigeonpea planted at moderate row of 75 cm intercropped with 2 rows of groundnut recorded maximum monetary value of pigeonpea due to compatible existence of crop components. The results revealed that the highest level of optimum fertility for higher yield and economic returns in pigeonpea based cropping system. Pigeonpea planted at 75 cm row distance intercropped with 2 rows of groundnut gave higher monetary advantage due to combined higher intercrops yield.

Higher fertility resulted higher monetary advantage probably for obvious reasons of higher yield due to better nutrition. The monetary advantage based on LER indicates superior economic viability of pigeonpea based intercropping with greengram and groundnut. Among the fertility levels there was steady increased in monetary advantage with increase in fertility level.

Economics:

The economics feasibility in terms of gross and net returns and benefit cost ratio showed that intercropping system gave higher returns and benefit: cost ratio than sole cropping of component crops. However, among the cropping system, intercropping of pigeonpea at row spacing of 75 cm with 2 rows of groundnut fetched higher gross and net returns and benefit-cost ratio which is mainly owing to higher economic production in this system. There was however a marginal increase in monetary returns in the higher level of fertility and the benefit-cost ratio showed a declining trend of the highest fertility level.

Uptake of NPK:

Spatial arrangement, types of intercrops and fertility levels showed pronounced effect on uptake of major nutrients by the base crop. Intercropping of pigeonpea at 100cm row spacing with 3 rows of groundnut exhibited higher uptake of N, P and K by pigeonpea over sole cropping. This was mainly due to fixation of N by legume intercrops resulting in higher uptake by crop. Higher availability of nutrients at wide row spacing of pigeonpea improved the physiological and metabolic functions inside the crop which led to higher biomass production which might be reason for higher uptake of nutrients. The results and land support to findings of Rana *et al,* (1999). Groundnut as intercrop with pigeonpea at wider space showed higher uptake of nutrients like NPK. Appreciable increase in NPK uptake of pigeonpea and intercrops seems primarily due to increased NPK content of plant owing to greater availability of these nutrients in the root zone and absorption by the crops.

Soil carbon content and NPK content:

The actual organic carbon and available NPK content of soil after harvest of crops is higher in number of intercropping systems and lower under sole pigeonpea. In intercropping pigeonpea planted in rows 100cm space along with intercrops recorded maximum content of organic carbon and available NPK. At reduced planting distance of pigeonpea at 50cm organic carbon and NPK tended to decline.

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Foliar Application of Boron and Molybdenum in Cauliflower Under West Central Table Land Zone of Odisha

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Abstract

The field experiment was conducted to study the Foliar application of boron and molybdenum in cauliflower under west central table land zone of Odisha". The treatments taken are farners practice, sole application of 100 ppm Boron at 10 days interval as treatment-1 and combine application of 50 ppm Boron & 50 ppm Molybdenum at 10 days interval as treatment-2. The results indicated that the foliar application of 50 ppm Boron in addition with 50 ppm molybdenum at 10 days interval given higher curd weight(917g), curd length (10.8 cm) and curd diameter (18.4 cm) in comparison to the only application of 100 ppm Boron at 10 days interval. Similarly, the combine application of boron and molybdenum given higher yield (328q/ha) in comparison to the sole application of boron. The highest economic study was seen in the TO2 (50 ppm Boron + 50 ppm Molybdenum) i.e. highest net return (Rs. 112690) and B:C ratio (2.34). Irrespective of the treatment tested, the combine application of 50 ppm Boron with 50 ppm Molybdenum was recommended for micronutrient application in cauliflower for higher crop growth and yield.

Key words : Boron, Molybdenum, cauliflower, Curd, yield etc

Introduction

Cauliflower (Brassica oleracea var. botrytis L.), which belongs to family Brassicaceae and genus Brassica, is a fast growing annual and herbaccous vegetable crop (Anonymous, 2020). The curd wihich is the edible part, white in colour and enclosed by inner leaves before its exposure (Dixit et al. 2020). ln India cauliflower was grown in 453 thousand hectares area having a total production of 8668 thousand metric ton (Anonymous, 2017). Cauliflower very well grown in macronutrients like Nitrogen, Phosphorous and Potassium. However, micronutrients are also very much required specially Boron and molybdenum for growth and increasing the yield of cauliflower (Rahman et al. 2007). Application of Boron increased plant height, number of leaves per plant, length and width of the leaf, plants spread, main head weight and head yield both per plant and per hectare (Moniruzzaman et al. 2007). In Boron deficiency, water soaked areas appear on the stem and head surface, hollow seen on the stem and brown colour shown in curd. In molybdenum deficiency chlorosis of leaf margins appears on young plant and white colour seen in whole leaf (Ningawale et al., 2016). In Odisha application of fertilizer rate has already increased then earlier in crop production but micronutrient application in soil has totally neglected. Therefore, rational and optimum use of micronutrient coupled with soil test recommended fertilizer would be beneficial for increasing the curd yield per unit area.

Materials and methods

A field experiment was conducted during rabi 2021-22 at village Bargaon and Brahmanidunguri of Bolangir and Loisingha block of Bolangir district of Odisha to study the "Foliar application of boron and molybdenum in cauliflower under west central table land zone of Odisha" under On-farm testing programme of Krishi Vigyan Kendra, Bolangir, Odisha. The experiment was laid out is a Randomized block design (RBD) with seven replications. The treatments drawn in farmers practice as recommended dose of fertilizer (120:40:50) only, in TO1 as soil test-based fertilizer dose with three foliar spray of 100 ppm boron (as borax) at 10 days interval and inTO11 as soil test-based fertilizer dose with three foliar spray of 50 ppm boron with 50ppm molybdenum (as Ammonium Molybdate) at 10 days interval. The soil of the experimental field was sandy loam in texture with pH 6.1, 0.30 % organic carbon, 228 kg/ha nitrogen, 14 kg/ha phosphorous and 121 kg potassium and 0.41% boron respectively. The curds were collected after harvest the data were recorded on various parameters like curd weight, yield and economics etc.

Results and Discussion

Study on physiological parameters:

The foliar application of boron and molybdenum bas becn increased thc curd weight from 761 to 917g. curd length from 8.3 to 10.8 cm and curd diameter from 14,2cm to 18,4cm (Table-2). However, the lowest data recordcd in the farmers practice whercas highest data recorded in ne treatment 2.

The application of 10 ppm boron increases 18.6 per cent curd weight(903g), 21.6 per cent curd length (10.lcm) and 26 per cent curd diameter (17.9cm) over farmer's practice. The combine application of 50ppm boron and 50 ppm molybdenum increases 20.4 per cent curd weight over farmer practice and 1.6 per cent over TO1;30.1 per cent curd length over farmer practice and 6.9 per cent over TO1: 29.5 per cent curd diameter over farmer practice and 2.7 percent over TO1 (Table-1). The combine application of boron and molybdenum significantly increases the curd weight, length and diameter, similar results found by the Rahman *et al.* (2021).

Study on yield

The curd yield varied significantly between 281 to 328 q/ha whereas the lowest was seen in farmers practice 281g/ha and highest was seen in TO2 328q/ha (Table-2). The farmers practice recorded 281g/ha. The application of 100 ppm Boron recorded 31lq/ha curd yield which is 10.6 % increase in yield over farmer practice. The combine application of 50 ppm boron and 50 ppm molybdenum recorded 328 q/ha curd yield which is 16.7 percent increase in yield over farmer practice and 5.46 % over TO1 (Table-2). The combine application of 'B' and 'Mo' recorded significantly highest curd yield over the only application of boron, This findings are in confirmation with the findings of Mahmud (2005).

TABLE 1. Efect of Boron and Molybdenum on curd weight, length and diameter

Treatments	Weight of curd (g)	Curd length (cm)	Curd diameter (cm)
FP	761	8.3	14.2
TOI	903	10.1	17.9
TO2	917	10.8	18.4
CD (0.05)	51.3	0.38	0.21
CV (%)	7.32	1.23	2.86

TABLE 2. Efect of Boron and molybdenum on crude yield

Treatment	Crude yield (q/ha)
FP	281
TO1	311
TO2	328
CD (0.05)	3.13
CV (%)	6.32

Study on Economic parameters:

The application of micronutrients significantly increases the economic return. The cost of cuUivalion varied between Rs. 77850 to Rs. 84110, gross return from Rs. 168600 to Rs. 196800, net return Rs. 90750 to Rs. 112690 and B:C ratio from 2.16 to 2.34 (Table-3). The lowest was seen in the fanner practice whereas highest was seen in the T02.

Table 3. Effect of Boron and molybdenum on Economic study

Treatment	Cost of cultivation	Gross return	Net return	B:C ratio
FP	77850	168600	90750	2.16
TOl	82170	186600	104430	2.27
T02	84110.	196800	112690	2.34

In farmer practice the cost of cultivation was Rs. 77850 where as application of Boron increases 5.5 percent i.e. Rs. 82170 and application of both boron, molybdenum increases 2.36 per cent over sole application of boron. The gross return increases 10.67 per cent i.e., Rs. 186600 in TOl over FP and 5.46 percent i.e. Rs. 196800 in T02 over TOl, The net return increases 15.77 percent i.e., Rs. 104430 in TOl over Farmer practice and 7,90 percent i.e. Rs. 112690 in T02 over TOl. Similarly, the B:C increases 5.09 percent i.e. 2.27 in TOl over FP and 3.08 percent i.e. 2.34 in T02 over TOl.

Conclusion:

The foliar application of 50 ppm Boron in addition with 50 ppm Molybdenum at 10 days interval given higher curd weight (917g), curd length (10.8 cm) and curd diameter (18.4 cm) in comparison to the only application of 100 ppm Boron at 10 days interval. Similarly, the combine application boron and molybdenum given higher yield (328q/ Jia) in comparison to the sole application of boron. The highest economic study was seen in the T02 (50 ppm Boron + 50 ppm Molybdenum) i.e. highest net return (Rs. 112690) and B:C ratio (2.34). Irrespective of the treatment tested, the combine application of 50 ppm Boron with 50 ppm Molybdenum was recommended for micronutrient application in cauliflower for higher crop growth and yield.

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Effect of Foliar Nutrition on Growth and Productivity of Black Gram (*Vigna mungo* L.) in Lower Gangetic Alluvial Soil of West Bengal

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Abstract

An experiment was carried out at the Agricultural Experimental Farm of Calcutta University, Baruipur, South 24 Parganas situated in the Gangetic alluvial soils of West Bengal in the year of 2022 to study the effect of foliar nutrition on growth and productivity of black gram (*Vigna mungo* L.). There were altogether 12 treatments like Water Spray, KNO_3 @ 0.5%, NPK 20:20:20 @ 0.5%, DAP @ 2%, NPK 10:26:26 @ 2%, KNO_3 @ 0.5% + Boron @ 0.1%, NPK 20:20:20 @ 0.5% + Boron @ 0.1%, DAP @ 2% + Boron @ 0.1%, NPK 10:26:26 @ 2% + Boron @ 0.1%, Boron @ 0.1%, Urea @ 2% and Urea @ 2% + Boron @ 0.1% at pre flowering stage and post flowering stage of black gram with special reference to scanning their effect on growth and productivity of the black gram during summer season. The experiment was conducted in randomized block design with three replications. The crop was sown on 10.03.2022 and harvested on 25.05.2022. A recommended dose of fertilizers was applied @ N: P_2O_5: K_20 - 20:40:20 kg ha^{-1} in the form of Urea, Single super phosphate and Muriate of potash as basal dose. The variety of the black gram crop was B-76. The result in general, indicates that the application of foliar nutrients had a great influence on yield contributing characters and seed yield of black gram. The investigation clearly showed that significantly highest seed yield (1400 kg ha^{-1}) was recorded with foliar application of NPK 20:20:20 @ 0.5% + Boron @ 0.1% followed by NPK 10:26:26 @ 2% + Boron @ 0.1% (1356 kg ha^{-1}). Lowest seed yield (924 kg ha^{-1}) was obtained from water sprayed control treatment. The seed yield was increased up to 51.51% with the application of NPK 20:20:20 @ 0.5% + Boron over control that was followed by spraying of NPK 10:26:26 @ 2% + Boron @ 0.1% and this improvement in yield to the tune of 46.75% over control. Similar trends were also noticed in yield contributing characters of the crop. Sole application of KNO_3 @ 0.5%, NPK 20:20:20 @ 0.5%, DAP @ 2%, NPK 10:26:26 @ 2%, Boron @ 0.1% and Urea @ 2%, also recorded higher seed yield over water spray control treatment on black gram. It is interesting to note that even soil grade fertilizers like NPK 10:20:26 and DAP which are easily available to the farmers door step, enhanced seed yield of black gram and were comparable to other foliar grade nutrients tested. One interesting observation was that Boron plays synergistic role in the absorption of NPK which inturn increased in the economic yield of the black gram. NPK 10:26:26 @ 2% + Boron @ 0.1% was found to be most cost effective foliar nutrient as it resulted highest B : C ratio (3.45). Thus, it is inferred from the present experiment that foliar application of NPK 20:20:20 @ 0.5% + Boron @ 0.1% at pre flowering stage and post flowering stage is found to be beneficial to increase the seed yield of black gram.

Pulses are a vital part of the Indian agriculture sector after cereals and oilseeds crops because it is the second important constituent of diet after cereals. India is the largest grower and consumer of pulses in the world. Pulses are essential in regards to the contribution to human nutrition and also in respect of their contribution to farmer's income. Pulses are important crops for food security, fighting malnutrition, improving poverty, improving human health and enhancing agricultural sustainability (Calles *et al*. 2019). Pulses can be grown on a varied soil series and under climatic conditions, and play an important role in crop rotation, inter-cropping and mixed cropping and maintaining soil fertility through nitrogen (N) fixation in soil (Maitra *et al*. 2021). The growth rate for area, production and productivity have remained very low (0.06, 0.65 and 0.59 %) as compared to cereals due to which India has to import 3-4 million tons of pulses every year to meet its domestic demand (Purushottam and Singh 2015). Black gram is one of the important pulse crops in West Bengal and cultivated in summer, kharif and post-kharif season (Ghosh *et al*. 2013). During 2014-15, in West Bengal overall dry yield rate was 686.44 kg ha^{-1} and the production was 42332 tonnes and major black gram growing districts in West Bengal are Murshidabad, Nadia and Malda with production of 11443 tonnes, 10759 tonnes, 10569 tonnes respectively during 2015 (Anonymous 2016). The protein content of black gram ranged from 21.2 to 31.1 percent, with an average of 25.1 percent. Black gram also contains 59.6 percent carbohydrate, 24 percent protein, 1.4 percent fat, 0.9 percent fiber. It is also rich in fibre, several vitamins (thiamin, riboflavin and niacin) and minerals like iron and calcium (Girish *et al*. 2012). Foliar feeding is a technique of feeding plants by applying liquid fertilizer directly to their leaves. The absorption takes place through their stomata and also through their epidermis. In many cases aerial spray of nutrients is preferred and gives quicker and better results than the soil application (Jamal *et al.* 2006). There is a direct link between foliar feeding and the activities of the enzymatic systems of the plant. Foliar spraying enables nutrients to get at the location of food synthesis directly, leading in zero waste, quick food delivery and less need for fertiliser which results significantly acceleration in crop growth. Further, soil application of nutrients is often not enough to meet the growing crop demand particularly in short duration crop like black gram, as it is basically indeterminate in habit of flowering and fruiting, there is a continuous competition for available assimilates between vegetative and reproductive sinks throughout the growth period. Foliar nutrition with N at later stage of crop growth delays the synthesis of abscisic acid and promotes cytokinin activity and causes high chlorophyll retention and thereby photosynthetic activity in effective leaves for supply of current photosynthates to the grains resulting in higher yield (Sarkar *et al*. 2007). Boron is the most widespread high-yield limiting micronutrient. In plant, Boron plays an important role in synthesis of cell walls, transport of sugar, differentiation of cells. In terms of yield, foliar nutrition is more efficient than soil fertilization for both macro and micronutrients in different soil types (Ali *et al.* 2008). Multi-nutrient foliar feeding products are often the most effective and may correct nutrient deficiencies giving increases in growth and development (El-Azab *et al.* 2012). Foliar application of nutrition is most economical way of fertilization to achieve quality production and yield, especially when sink competition for carbohydrates among plant organs take place, while nutrient uptake from the soil is restricted (Singh 2007). This experiment was mainly done to find out the effect of foliar nutrition on growth and productivity of black gram in lower gangetic alluvial soil of West Bengal.

Materials and Methods

The present experiment was designed to study the performance of black gram (*Vigna mungo* L.) as affected by foliar spraying of different nutrients at pre flowering stage and post flowering stage was conducted at the Agricultural Experimental Station of Calcutta University, Baruipur, South 24 Parganas, West Bengal (88°26" longitude and 22°22" N latitude) in the month of March of 2022. The soil of experimental site was medium fertility, clay loam in texture, slightly acidic in reaction (6.3), medium in organic carbon (0.62%), low in available nitrogen (179 kg ha^{-1}) but medium in available phosphorus (30 kg ha^{-1}) and potassium (261 kg ha^{-1}). The experiment was laid in a randomized block design with 12 treatments and 3 replications using variety B-76. Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) were applied at a recommended dose of 20 kg N, 40 Kg P_2O_5, and 20kg K_2O per hectare. The fertilizers were applied as a basal dose at the time of final land preparation. The fertilizers were used in the form of Urea, Single super phosphate and Muriate of potash respectively. Seeds were sown @ 25 kg ha^{-1} and at a depth of 2-3 cm by hand hoe with row to row spacing of 25 cm and plant to plant spacing of 10 cm on 10^{th} of March 2022. The foliar treatments were (T_1) Water Spray, (T_2) KNO_3 only (0.5%), (T_3) NPK 20:20:20 (0.5%), (T_4) DAP (2%), (T_5) NPK 10:26:26 (2%), (T_6) KNO_3 (0.5%) + Boron (0.1%), (T_7) NPK 20:20:20 (0.5%) + Boron (0.1%), (T_8) DAP (2%) + Boron (0.1%), (T_9) NPK 10:26:26 (2%) + Boron (0.1%), (T_{10}) Boron (0.1%), (T_{11}) Urea (2%) and (T_{12}) Urea (2%) + Boron (0.1%). Nutrient solutions were applied @ of 500L ha^{-1} as foliar spray at pre flowering stage and post flowering stage in the afternoon hours of dry sunny days. Four irrigations were done at 10 days interval. Thinng was done at 15 DAS to maintain uniform crop stand. Two hoeing at 20 and 40 DAS respectively were done with spade to remove the weeds and to loosen the soil. The crop was harvested manually on 25th of May 2022. The soil of the experimental plot was of medium fertile clay loam in texture and nearly neutral in reaction. Four irrigations were done at 15 days interval. The crop was harvested manually on 21st of May 2016.

Results and Discussion

Growth parameters *viz.* plant height, dry matter per plant, number of branches per plant as influenced by various foliar treatments have been presented in Table-1. The data clearly indicates that at the time of first observations at 30 DAS and second observations at 45 DAS, the maximum plant height was recorded with NPK 20:20:20+BORON (10.06 cm) and (19.26 cm) respectively but they were not significantly different. But at the later growth stages i.e. at 60 DAS, the plant height varied significantly. Among the foliar sprays, spraying with urea recoreded maximum plant height (31.64 cm) followed by NPK 20:20:20+Boron (30.69cm). This result is also in conformation with the reports of (Laghari M and Ali M A 2017) who also reported increase in plant height in wheat due to foliar application of urea. (Arif *et al.* 2006) also reported significant increase in plant height of wheat crop with foliar application of different nutrients individually or in combination. Results of this study are supported by (Bameri *et al.* 2012) as they reported chlorophyll and Indole-acetic acid (IAA) formation were increased with the spray of Boron which improved the height of plant. At 30 DAS, dry matter production due to application of different foliar nutrition had no significant effect. But at later stages of growth, i.e at 45 DAS and 60 DAS it varied significantly. Highest dry matter per

TABLE 1. Influence of foliar application of nutrient on growth parameters of blackgram

Treatments	Plant height (cm)			Dry matter plant^{-1} (g)			No. of branches plant^{-1}
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	
T_1 - Water Spray	9.90	15.98	23.13	4.20	5.03	6.9	5.56
T_2 - KNO_3 only (0.5%)	9.92	18.04	29.44	3.66	5.96	6.86	7.56
T_3 - NPK 20:20:20 (0.5%)	9.97	18.34	28.03	4.13	6.91	8.00	6.56
T_4 - DAP (2%)	9.94	16.48	27.28	3.90	6.21	8.36	6.96
T_5 - NPK 10:26:26 (2%)	10.01	18.99	30.18	4.20	7.03	8.81	7.63
T_6 - KNO_3 (0.5%) + Boron (0.1%)	10.06	19.26	30.69	4.16	7.70	9.36	8.66
T_7 - NPK 20:20:20 (0.5%) + Boron	10.01	18.99	30.18	4.20	7.03	8.81	7.63
(0.1%)	10.06	19.26	30.69	5.16	7.70	9.36	8.66
T_8 - DAP (2%) + Boron (0.1%)	9.99	18.76	28.37	3.90	6.86	8.43	7.23
T_9 - NPK 10:26:26 (2%) + Boron	10.05	19.03	30.37	4.1	7.53	9.12	8.23
(0.1%)	9.98	18.43	26.37	3.96	6.80	7.20	7.23
T_{10} - Boron (0.1%)	9.92	16.93	31.64	3.90	5.16	7.13	6.30
T_{11} - Urea (2%)	9.99	18.06	29.14	3.90	6.86	7.90	6.56
T_{12} - Urea (2%) + Boron (0.1%)	0.04	0.83	0.87	0.12	0.17	0.20	0.62
S.Em (±)	NS	NS	2.56	NS	0.51	0.59	NS
CD (P=0.05)							

Table 2. Influence of foliar application of nutrients on yield attributing characters and seed yield in blackgram

Treatments	No. of pods $plant^{-1}$	Test weight (g)	Seed yield (kg ha^{-1})	Benefits : cost ratio
T_1 - Water Spray	16.60	38.50	924	1.98
T_2 - KNO_3 only (0.5%)	19.90	45.96	1269	2.98
T_3 - NPK 20:20:20 (0.5%)	24.56	43.70	1234	2.95
T_4 - DAP (2%)	21.90	42.80	1200	2.82
T_5 - NPK 10:26:26 (2%)	25.56	44.10	1261	3.03
T_6 - KNO_3 (0.5%) + Boron (0.1%)	26.90	46.50	1340	3.18
T_7 - NPK 20:20:20 (0.5%) + Boron	30.56	48.91	1400	3.45
(0.1%)	26.56	46.16	1284	3.06
T_8 - DAP (2%) + Boron (0.1%)	28.56	46.70	1356	3.31
T_9 - NPK 10:26:26 (2%) + Boron	22.23	44.70	1202	2.86
(0.1%)	18.23	42.46	11.40	2.67
T_{10} - Boron (0.1%)	21.90	43.50	11.96	2.83
T_{11} - Urea (2%)	1.78	1.29	33.30	
T_{12} - Urea (2%) + Boron (0.1%)	5.23	3.79	97.67	
S.Em (±)				
CD (P=0.05)				

plant was observed with foliar feeding of NPK 20:20:20+Boron (9.36 g) which was on par with foliar application of NPK 10:26:26+Boron (9.12 g) and KNO_3+Boron (8.81g) at 60 DAS. This might have resulted into better interception, absorption and utilization of energy, leading to higher photosynthetic rate and finally more accumulation of dry matter by the plants. This result is also in conformation with the reports of (El-Azab M E 2016) in cowpea. These results are in concurrence with the reports of (Bochalya *et al*. 2021) in sunflower. Number of branches per plant did not significantly with foliar application of nutrients.

Foliar application of NPK 20:20:20 + Boron recorded maximum number of branches per plant (8.66). These results are in line with the finding of (Mandre *et al*. 2020) in black gram. (Bera *et al.* 2008) reported that the significant increase in growth characters of black gram might be due to combination of foliar application of nutrient and growth regulator which play a major role in growth development and metabolism of black gram.

Data pertaining to yield contributing characters *viz.* number of pods per plant and test weight (1000 seed weight) and seed yield as influenced by various foliar treatments were recorded and analysed statistically (table-2). The perusal of data clearly reveals that application of NPK 20:20:20 + Boron recorded significantly higher pods per plant (30.56) which was on par with 10:26:26 + Boron (28.56) and followed by KNO_3 + Boron (26.90). The foliar application of nutrients through NPK 20:20:20 + Boron at flower initiation stage might have reduced flower drop. This might have significantly increased the number of pods per plant. A similar report with increased number of pods per plant by foliar application of NPK by (Solaiappan *et al.* 2002) in redgram.

Maximum test weight has been recorded in NPK 20:20:20 + Boron (48.91 g) which was on par with 10:26:26 + Boron (46.70 g). These findings are in conformity with the reports of (Thakur *et al.* 2017) in black gram. The similar results in pigeonpea was reported by (Teggelli *et al.* 2016). Foliar application of nutrients influenced seed yield of black gram significantly over spraying of water only. Among the all treatments, foliar application of NPK 20:20:20 + Boron recorded significantly highest seed yield (1400 kg ha^{-1}) which was closely followed by NPK 10:26:26 + Boron (1356 kg ha^{-1}) and KNO_3 + Boron (1340 kg ha^{-1}). The seed yield was increased up to 51.51% with the application of NPK 20:20:20 @ 0.5% + Boron over control that was followed by spraying of NPK 10:26:26 @ 2% + Boron @ 0.1% and this improvement in yield was in tune of 46.75% over control. The improvement in yield attributes possibly is due to application of nutrients at critical stages of crop growth and those were effectively absorbed by black gram and translocated more effectively for developing pods and proper filling of seeds. These results are in line with the finding of (Das and Jana 2015) in greengram, black gram, lathyrus, lentil and chickpea. Yield enhancement in wheat due to foliar application of NPK was also reported by (Sharma 2016). It was interesting to note that all the tested foliar nutrient enhanced seed yield when they were tank mixed with foliar Boron. Boron influences the absorption of NPK which inturn increased in the seed yield of the black gram. (Pandey and Gupta 2013) reported that the foliar application of boron increased the yield parameters like number of pods, pod size and number of seeds formed per plant, it also improved the seed yield and seed quality in black gram. It is interesting to note that even soil grade fertilizers like NPK 10:20:26 and DAP which are easily available to the farmers door step, enhanced seed yield of black gram significantly and were comparable to other foliar grade nutrients tested. Thus it can be concluded that NPK 20: 20: 20 + Boron recorded significantly highest yield contributing characters and seed yield of black gram and also recorded highest B : C ratio (3.45) and Boron plays synergistic role in the absorption of NPK which inturn increased in the economic yield of the black gram.

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Analysis of Genetic Variability, Heritability and Genetic Advance of 25 Indian Mustard (*Brassica juncea*) Genotypes

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Abstract

The present investigation was done with 25 Indian mustard (*Brassica juncea*) genotypes at the agriculture research farm of Department of Genetics and Plant breeding of Lovely Professional University. The experiment was conducted during the Rabi season of 2021 by using RCBD design and with 3 replications to study the genetic variability by PCV and GCV value, Heritability and Genetic Advance. We found high PCV and GCV value in trait number of secondary branches per plant (PCV= 23.98% and GCV= 22.48%), highest heritability shown by seed yield per plant (91.8%), highest genetic advance as % of mean shown by number of secondary branches per plant (43.41%) followed by seed yield per plant (37.57%).

Introduction

Mustard and Rapeseed is one of the most important crops among the oilseed crops. It is grown in both tropical and sub-tropical regions around the world. Mustard is a crop of the Brassicaceae family with several applications. *Brassica juncea*, which produces around 80% of the total rapeseed-mustard production in the country. It is the most common and important Brassica species for oil extraction. During 2017-18, the estimated area, production, and yield of rapeseed-mustard in the globe were 36.68 mha, 72.42 mt, and 1974 kg/ha, respectively, among the numerous oilseed crops farmed globally. India accounts for 19.80% of total area and 9.8% of total production globally. The estimated geographical area was 6.07 Mha, with the production of 7.92 mt. and the productivity were 1304 kg/ha in case of rapeseed and mustard (Anon. 2017-18). As per the reports *Brassica juncea* or the Indian mustard was originated in a number of locations in Western and Central Asia. Among them Central Asia is thought to be the main center of origin of Indian mustard, with secondary center of origin in Central and Western China. In Asia, India is first in both acreage and production of rapeseed and mustard.

For each crop development initiative, yield is a critical quantitative feature. The type and quantity of variability present in the genotypes, as well as the heritability of desirable qualities, are all factors in genetic improvement for the quantitative traits. In order to increase production of Indian mustard, it is necessary to generate high yielding cultivars, which necessitates a systematic breeding method. The genetic variability contained in the breeding material or among the taken genotypes plays an important role in the development of the breeding program for developing superior cultivars or hybrids. For making effective selection of some varieties, necessity is the evaluation of factors such as phenotypic coefficients of variation and the genotypic coefficients of variation, heritability in broad sense (BSH) and genetic progresses as a percentage of mean (Manjunath *et al.,* 2017). Any applied breeding effort requires a thorough grasp of the genetic variables that influence the inheritance of yield-contributing traits.

Materials and method

The experiment was carried out at the experimental farm, Department of Genetics and Plant breeding, School of Agriculture, Lovely Professional University, Punjab. It is done in the Rabi season of 2021. Subtropical conditions prevailed during field preparation and seed sowing in the North-Western plains of mustard production. Experimentation was conducted on sandy loam soil with a high irrigation percentage and a moderate water-holding capability.

Total 25 genotypes (Indian mustard) are taken and experimented in RCBD (Randomized complete block design) design with 3 replications. These 25 genotypes are Rajat (PCR 7), RGN 48, Maya, Pusa Vijay (NPJ 93), RH119, Seeta, PM 25 (NPJ 112), NRCDR 601, Aravali (RN 393), PBR 97, Pusa Bold, RH 749, Krishna, CS 56, RH 30, RL 1359, DRMRIJ 31, NRCHB 101, CS 60, Vaibhav, RGN 73, NRCDR 2, Geeta, PBR 210, Laxmi (RH 8812) and their recorded traits are days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, seed yield per plant (gm), no of siliqua per plant, no of seeds per siliqua, siliqua length, harvest index and 1000 seed test weight.

Statistical analysis is done for those recorded observations are analysis of variance (method given by Panse and Sukhatme 1952), Heritability Broad sense and narrow sense (method given by Hanson *et al.,* 1956), Genetic advance (given by Johnson *et al.,* 1955) and Phenotypic and Genotypic coefficient of variation (given by Burton 1952, Singh and Chaudhary 1985).

Results and discussion

The Analysis of variance (ANOVA) of the mentioned 25 varieties and their 11 characters are tabulated on the Table 1. The ANOVA table data interpret that all the taken characters are significant at both 5% and 1% level. So, those traits can be used for the selection purposes as they showing variability. Similar results were also obtained by Tripathi, N., et al. (2020) Rout, S., et al. (2018) Yadav, S., et al. (2018). In their study analysis of variance, the characters showed highly significant difference among genotypes.

Table 1. Table of Analysis of Variance (ANOVA)

S. no.	Characters/Parameters	Mean sum of squares			
		CV %	Replication	Treatment	Error
1.	Days to 50% flowering	7.191	59.29	92.47**	24.48
2.	Days to maturity	0.668	0.00003	3.89**	0.89
3.	Number of primary branches	11.502	11.82	6.95**	0.78
4.	Number of secondary branches	14.480	32.13	100.17**	12.16
5.	Plant height	9.760	84.15	1083.51**	380.80
6.	Number of siliquae per plant	14.147	8857.84	14384.68**	3559.95
7.	Siliqua length	7.757	0.15	0.80**	0.17
8.	Seeds per siliqua	10.396	3.62	24.71**	3.94
9.	Harvest index	12.350	8.06	19.34**	2.69
10.	1000 seed test weight	7.822	0.06	0.52**	0.07
11.	Seed yield per plant	9.877	15.05	80.77**	6.64

Table 2 showing the Mean performance along the range of the variation, CD value, Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV) value, heritability% in broad sense, genetic advance and genetic advance as % of mean. environmental influences.

Coefficient of variation (PCV and GCV):

The high estimate (>20%) of phenotypic (PCV) and genotypic (GCV) coefficients of variation was shown only in the case of number of secondary branches (PCV= 23.98% and GCV= 22.48%). Moderate estimates (<20%- >10%) of PCV and GCV were shown in case of number of primary branches (PCV= 19.81% and GCV= 18.66%), number of siliquae

TABLE 2. Analysis of Mean, Range, CD value, PCV and GCV, Heritability % in Broad sense Genetic advance and Genetic advance as % of mean

S. No.	Parameters/ Characters	Mean	Range Lowest	Highest	SE	CD (5%)	GCV (%)	PCV (%)	Herit ability (Broad sense)	Genetic Advance (5%)	Ga M (%)
1.	Days to 50% flowering	68.813	56	77	2.857	8.123	6.918	8.068	73.5	8.409	1
2.	Days to maturity	141.2 41	139	142	0.545	1.549	0.709	0.807	77.1	1.811	1
3.	Number of primary branches	7.688	3.94	10.92	0.510	1.451	18.664	19.810	88.8	2.785	3
4.	Number of secondary branches	24.09	6.62	33.23	2.014	5.726	22.483	23.987	87.9	10.458	4
5.	Plant height	199.9 32	168.8 53	234.12	11.26 6	32.03 6	7.655	9.505	64.9	25.390	1
6.	Number of siliquae per plant	421.7 34	295.6 6	584.83	34.44 7	97.95 0	14.243	16.419	75.3	107.34 3	2
7.	Siliqua length	5.461	4.64	6.80	0.244	0.695	8.349	9.474	77.7	0.828	1
8.	Number of seeds per siliqua	19.11 5	13.60	25.62	1.147	3.262	13.764	15.015	84.0	4.968	2
9.	Harvest index	13.29	8.66	17.97	0.947	2.694	17.725	19.106	86.1	4.502	3
10.	1000 seed test weight	3.529	2.71	4.566	0.159	0.453	10.963	11.857	85.5	0.737	2
11.	Seed yield per plant	26.10 5	16.47 0	37.193	1.488	4.233	19.042	19.878	91.8	9.810	3

Genetic variability:

The basic prerequisite for carrying out any crop enhancement effort is the presence of sufficient genetic heterogeneity. Generally, PCV values will be higher than their respective GCV values indicating that slight per plant (PCV= 16.41% and GCV=14.24%), number of seeds per siliqua (PCV= 15.01% and GCV= 13.76%), Harvest index (PCV= 19.10% and GCV= 17.72%), 1000 seed test weight (PCV=11.85% and GCV= 10.96%) and seed yield per plant (PCV= 19.87% and GCV= 19.04%). Number of secondary branches per plant, number of primary branches per plant, number of siliquae per plant, number of seeds per siliqua, Harvest index, 1000 seed test weight, and seed yield per plant has shown high to moderate PCV as well as GCV which signifies that for those characters simple selection program can be practice for the improvement purpose.

Heritability:

The ratio of genotypic variance to overall or phenotypic variance is known as broad sense heritability (BSH). Higher heritability characters are always recommended for selection. Heritability estimations in the broad sense were found high (>75%) in several characters, those are days to maturity (77.1%), number of primary branches (88.8%), number of secondary branches (87.9%), number of siliqua per plant (75.3%), siliqua length (77.7%), number of seeds per siliqua (84.0%), harvest index (86.1%), 1000 seed test weight (85.5%), seed yield per plant (91.8%) which indicates Such characters are the least affected by environmental factors, thus choosing them during breeding may be a good idea. Because high BSH shows high influence of genetic factors. Moderate estimates (50-75%) were observed for days to 50% flowering (73.5%) and plant height (64.9%) which indicates those characters are highly influenced by the environmental effects and selection for the genetic improvement of those characters would be difficult due to the masking effect.

Genetic advance in % of mean:

Genetic advance is defined as an increase in the mean genotypic value of a chosen plant population over its parental population. It is a measurement of genetic improvement due to selection. The maximum genetic advance in % of mean (>20%) were recorded for number of primary branches per plant (36.22%), number of secondary branches per plant (43.41%), number of siliquae per plant (25.45%), number of seeds per siliqua (25.98%), harvest index (33.87%), 1000 seed test weight (20.88%) and seed yield per plant (37.57%) which indicates the character is governed by additive genes and selection will be rewarding for those traits. The medium estimates of genetic advance in % of mean (10- 20%) were observed for the characters days to 50% flowering (12.21%), plant height (12.69%), siliqua length (15.15%). The character days to maturity (1.28%) only shows the low estimates (<10%) for the genetic advance in % of mean which indicates those characters are governed by non-additive genes and for the improvement of those character heterosis breeding should be used.

Similar results of heritability and genetic advance was also found in the studies of Jat *et al.* (2019), Roy et al. (2018), Akabari et al. (2015), Tiwari *et al.* (2017), Singh *et al.* (2020), Uzair *et al.* (2016) and Synrem *et al.* (2014).

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Scheduling of Irrigation in Zero Tilled Wheat and Fertilizer Management for Achieving Higher Yield Gangetic Alluvial Land

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Abstract

The results of the investigation conducted during winter seasons of 2020-21 and 2021-22 at Water Management Research Centre indicated that four irrigations one each at crown root initiation, maximum tillering, boot leaf stage and milk stage showed significant effect on growth parameters and physiological growth parameters of zero tilled wheat. Application of 100kg N+ 80kg P_20_5 + 80 kg K_2O ha proved most effective in enhancing almost all the growth and physiological parameters in zero tilled wheat.The same irrigation schedule and fertility level also showed conspicuous effect on chlorophyll content in wheat leaves.Four irrigations ones each at crown root initiation, maximum tillering, bout leaf stage and milk stage significantly and appreciably improved most of the yield contributing characters. Similarly, 160kg N + 80 kg P_20_5 and 80 kg K_2O/ha showed better manifestation ofyield attributes. Such irrigation schedule recorded 17.63 and 27.73% higher grain yield than schedule of second with irrigation at crown root,maximum tillering,flowering stage and milk stage and schedule three with irrigation at crown root, maximum tillering, boot leaf stage and flowering stage respectively on pooled basis. The highest level of fertility resulted in maximum grain yield in zero tilled wheat. Such irrigation scheduled and fertility level accounted for higher uptake of nutrients in zero tilled wheat.

Introduction

Yield of wheat crop under zero tillage system is governed by many factors among which availability of moisture and fertilizers are most important. Adequate fertilization in consistency with availability of moisture at the critical stage of crop growth is vital for optimum production under the conditions of resource conservation. The non-availability of irrigation at crown root initiation and flowering stages reduces grain yield of wheat by 33 and 25% respectively (Deshmukh *et al.,*1992). Rice followed by wheat is the most productive system of crop production in north and eastern India. With the adoption of modern agronomic management, favourable soil moisture regime can be created by timely scheduling of irrigation (McDonal *et al.,* 1984). Similarly soil fertility can be maintained with the use of recommended fertilizers (Singh and Verma, 1990). Nutrients, water and tillage the three key inputs interact among themselves synergistically to improve the crop yield and hence the input use efficiency. Hence there is need to investigate the effects of scheduling irrigation and fertilizer on productivity of wheat following rice.

Materials and Methods

The field experiment was conducted during winter seasons of 2020-21 and 2021-22 at Water Management Research Station, Ranaghat, District Nadia, West Bengal. The experiment was conducted in New Alluvial Agro- Climatic Zone of West Bengal. The soil had 0.45% organic carbon with 35 kg available P_2O_5 and 260 kg available K_2O with soil ph 7.60. The experiment consisting of three irrigations scheduled (i) viz. irrigation at crown root initiation (CRI), maximum tillering (MT), boot leaf stage (BL) and milk stage (MK) scheduled (ii) viz. irrigation at crown root initiation (CRI), maximum tillering (MT), flowering stage (FL) and milk stage (MK) and scheduled (iii) viz. irrigation at crown root initiation (CRI), maximum tillering (MT), boot leaf stage (BL) and flowering stage (FL) keeping irrigation in main plots and from fertility levels N- P_2O_5- K_2O at 6kg/ha (F_0), N-P_2O_5- K_2O @ 80-40-40 kg/ha (F_1), N-P_2O_5- K_2O at 120-60-60 kg/ha (F_2) and N- P_2O_5-

K_2O at 160-80-80 kg/ha (F_3) in sub -plots was tested in split plot design replicated thrice. Wheat cultivar UP-262 was sown by the zero till seed cum fertilizer drill at spacing of 20 cm row distance at continuous sowing. Sowing was done in third week of November in both the years standard practices were followed for raising the crop. Growth analysis was done as procedure advocated by Watson, 1958.

Results and discussion

Wheat receiving four irrigations one each at CRI, MT, FL and MK stage recorded significantly taller plants as compared to plants irrigated other stages probably due to healthierplant growth having no moisture stress at critical crop growth. This schedule of irrigation helped in accelerating the cell expansion and translocation of photosynthates in apical region resulting in increase in plant height (Thompson and Chase, 1952). The increase in plant height with increase in fertility level upto 120 kg N + 60 kg P_2O_5 + 60 kg K_2O was due to conversion of synthesized carbohydrates into protein to form more protoplasm and this increases in number and size of cells which might cause an increase in plant height (Yadav *et al.* 1995). Higher soil moisture status at irrigation schedule of one maintained better plant water status which might have resulted in increase in cell elongation, call division, leaf expansion and more absorption of photosynthetically active radiation and thereby higher dry matter production (Table- 1)

More dry matter production with the highest level of NPK might be due to additive and complementary effect of growth attributing characters. Nitrogen (N) being an important constituent of chlorophyll, enzymes and proteins has a define role in increasing cell size and division (Black, 1967) which eventually increased drymatter productions.The increased leaf area index (LAI) indicates that the effects are more pronounced at higher level of irrigation at schedule one. Increased in LAL at the highest level of fertility was due to increase in leaf number and size in cell number under better nutritional environment (Li 1984).

Table 1. Effect of scheduling irrigation and fertility rate on Growth Parameters of Wheat

Treatments	Plant height (cm)		Dry matter (g/m^2)	
	2020-21	2021-22	2020-21	2021-22
I_1 = Irrigation at CRI, MT, BL, MK	101.86	103.92	929.00	991.26
I_2 = Irrigation at CRI, MT, FL, MK	98.45	99.38	822.25	886.36
I_3 = Irrigation at CRI, MT, BL, FL	98.02	09.73	725.75	785.55
S. Em (±)	2.76	2.8I	26.34	27.83
CD (P=0.05)	NS	NS	103.40	109.25
F_0 = N: P_2O_5: K_2O :: 0:0:0 kg/ha	87.74	89.50	221.33	235.07
F_1 = N: P_2O_5: K_2O :: 80:40:40 kg/ha	99.80	101.14	647.33	694.35
F_2 = N: P_2O_5: K_2O :: 120:60:60 kg/ha	105.80	106.89	1169.00	1250.26
F_3 = N: P_2O_5: K_2O :: 160:80:80 kg/ha	104.43	106.52	1265.00	1371.20
S. Em (±)	2.12	2.14	25.11	26.60
CD (P=0.05)	6.30	6.36	74.59	79.03

*CRI – Crown root initiation, MT- Maximum tillering, BL- Boot leaf stage, FL- Flowering stage, MK- Milking stage.

TABLE 2. Effect of scheduling irrigation and fertility rate on Physiological Parameters of Wheat

Treatments	Leaf Area Index LAI at maximum at 60 days		Corp Growth Rate (CGR) (g/m²/ day) at 60 days		Relative Rate (CGR) (g/g/ day) maximum at 45- 60 days	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
I_1 = Irrigation at CRI, MT, BL, MK	4.398	4.690	16.82	17.93	0.0939	0.0966
I_2 = Irrigation at CRI, MT, FL, MK	3.935	4.164	12.10	13.17	0.0813	0.0857
I_3 = Irrigation at CRI, MT, BL, FL	3.868	4.059	12.07	13.06	0.0936	0.0974
S. Em ($\pm$)	0.122	0.131	0.54	0.57	0.0025	0.0026
CD (P=0.05)	NS	NS	2.11	2.23	0.0099	0.0101
F_0 = N: P_2O_5: K_2O :: 0:0:0 kg/ha	1.970	2.116	2.64	2.82	0.0933	0.0961
F_1 = N: P_2O_5: K_2O :: 80:40:40 kg/ha	4.263	4.563	8.64	9.26	0.0945	0.0984
F_2 = N: P_2O_5: K_2O :: 120:60:60 kg/ha	4.990	5.166	20.56	21.95	0.0957	0.0995
F_3 = N: P_2O_5: K_2O :: 160:80:80 kg/ha	5.043	5.372	22.81	24.85	0.0749	0.0789
S. Em ($\pm$)	0.104	0.108	0.49	0.52	0.0020	0.0020
CD (P=0.05)	0.308	0.322	1.46	1.55	0.0059	0.0061

TABLE 3. Effect of scheduling irrigation and fertility rate on growth and yield contributing parameters of Wheat

Treatments	Net Assimilation Rate (NAR) (g/m²/ day) at 45-60 days		Chlorophyll at 70 days		Tiller/m²	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
I_1 = Irrigation at CRI, MT, BL, MK	5.175	4.069	0.59	0.63	303.8	463.45
I_2 = Irrigation at CRI, MT, FL, MK	5.561	4.194	0.48	0.51	266.20	470.56
I_3 = Irrigation at CRI, MT, BL, FL	6.026	4.904	0.54	0.57	266.55	383.52
S. Em ($\pm$)	0.135	0.107	0.02	0.02	8.58	9.73
CD (P=0.05)	0.546	0.420	0.04	0.04	NS	NS
F_0 = N: P_2O_5: K_2O :: 0:0:0 kg/ha	5.991	4.551	0.34	0.37	133.45	158.14
F_1 = N: P_2O_5: K_2O :: 80:40:40 kg/ha	6.112	4.840	0.53	0.57	237.80	287.79
F_2 = N: P_2O_5: K_2O :: 120:60:60 kg/ha	5.453	4.461	0.62	0.64	372.91	417.05
F_3 = N: P_2O_5: K_2O :: 160:80:80 kg/ha	4.793	3.404	0.66	0.70	370.28	439.18
S. Em ($\pm$)	0.111	0.089	0.01	0.01	7.50	8.93
CD (P=0.05)	0.328	0.264	0.04	0.04	23.19	26.54

Irrigation schedule one showed more crop growth rate (CGR) at 60-75 days of growth indicating irrigation at critical stages induced a late spurt in growth delaying in maturity and grain filling process. Highest level offertility recorded maximum CGR between 60 and 75 days of growth when LAI also attained the highest magnitude which accumulated higher dry matter.The better manifestation of RGR withirrigation schedule one at CRI, MT, BL, andMK stage might be owing to increased call turgidity, higher stomatal conductance and photosynthesis which favoured improvedplant growth parameters like LAI and CGR and better accumulation of dry matter in plant to favourable water balance maintained throughthis irrigation schedule one might have resulted in more accumulationof dry matter and crop growth rate and ultimately increase RGR. Fertility level showed progressively higher RGRup to highest level of fertility onaccount of make accumulation of day matter and CGR.The NAR increased maximally up to 45-60 days which was essentially an estimate ofcanopy photosynthesis achieved perunit leaf area and can be used as a measure of photosynthesis efficiency.

to higher uptake of nutrients resulting in synthesis of chlorophyll at higher level of fertility (Nehra *etal.* 2001)

Irrigation schedules and fertility levels showed pronounced effect on yield attributing characters in wheat. Irrigation schedule with one produced maximum number of tillers/m² due to sufficient availability of water at critical stages of water needs and better uptake of nutrients (Mcdonald, 1984). The maximum number of tiller/m² under the highest fertilityrate was possibly due to better growth and development of plant as well as improvement of physio-chemical properties due to addition of fertilizers (Kler and Walia, 2006). Maximum number of spikes/m² was

TABLE 4. Effect of scheduling irrigation and fertility rate on yield parameters of Wheat

Treatments	Spikelets / m^2		Length of spike (cm)		Number of spikelets	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
I_1 = Irrigation at CRI, MT, BL, MK	272.98	324.01	10.60	10.22	37.13	35.86
I_2 = Irrigation at CRI, MT, FL, MK	248.78	291.79	9.18	9.02	34.94	34.33
I_3 = Irrigation at CRI, MT, BL, FL	209.81	246.69	9.80	9.69	35.09	34.67
S. Em ($\pm$)	7.88	9.29	0.28	0.27	1.02	0.99
CD (P=0.05)	30.92	36.48	NS	NS	NS	NS
F_0 = N: P_2O_5: K_2O :: 0:0:0 kg/ha	122.48	140.92	8.34	8.07	27.74	26.9
F_1 = N: P_2O_5: K_2O :: 80:40:40 kg/ha	215.61	261.47	9.44	8.88	34.26	32.22
F_2 = N: P_2O_5: K_2O :: 120:60:60 kg/ha	322.72	378.83	10.91	10.69	40.09	39.29
F_3 = N: P_2O_5: K_2O :: 160:80:80 kg/ha	314.62	368.77	10.75	10.91	40.8	41.41
S. Em ($\pm$)	7.07	8.25	0.22	0.22	0.81	0.80
CD (P=0.05)	20.99	24.50	0.67	0.66	2.41	2.37

The depressing effect of irrigations schedule three and higher rate of fertility on NAR at 45-60 days was quite obvious becauseof relatively higherrate of expansion of leaf surface under ample supply of irrigation and nutrients (Watson, 1947). Crop plant irrigated at irrigation schedule onerecorded higher chlorophyll content in leaves. The variability with regard to sensitivity of chlorophyll content to irrigation and water supply might be related to variability to superoxide dismutase activity in leaves and leaf sheath (Yan *et al,*1995). The higher chlorophyll content in wheat with higher rate of fertility might be attributed

with irrigation schedule one probably due to adequate moisture supply. Favourable effect of highest fertility level on growth parameters might have enhanced number of spikes/m² which increased photosynthates supply to the spikelets.Irrigation did not show significant effect on length of spike in zero tilled wheat. However,appreciably longer length in spike was noted with irrigation schedule one possibly due to more favourable water regime in the root zone of the soil provided at important stage of growth. The ear length might have increased with supply of photosynthates to the sink due to release an availability of nutrients

TABLE 5. Effect of scheduling irrigation and fertility rate on yield parameters, grain and straw yield and harvest index of Wheat

Treatments	Test weight (G)		Grain yield (t/ha)		Straw Yield (t/ha)		Biological Yield		Harvest Index (%)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
I_1 = Irrigation at CRI, MT, BL, MK	32.90	35.43	2.90	3.60	6.66	7.12	9.56	10.72	31	33.61
I_2 = Irrigation at CRI, MT, FL, MK	32.98	35.13	2.49	3.05	6.19	6.57	8.69	9.62	29	32.28
I_3 = Irrigation at CRI, MT, BL, FL	35.15	37.76	2.26	2.83	5.36	5.75	7.62	8.58	31	33.81
S. Em ($\pm$)	0.88	0.95	0.08	0.10	0.19	0.20	0.27	0.30	0.8	0.90
CD (P=0.05)	NS	NS	0.32	0.40	0.74	0.79	1.06	1.19	NS	NS
F_0 = N: P_2O_5: K_2O :: 0:0:0 kg/ha	28.58	30.96	0.77	0.94	1.59	1.73	2.37	2.66	33	35.18
F_1 = N: P_2O_5: K_2O :: 80:40:40 kg/ha	33.50	36.44	1.97	2.45	4.79	5.22	6.76	7.67	29	32.22
F_2 = N: P_2O_5: K_2O :: 120:60:60 kg/ha	36.00	38.36	3.70	4.45	8.43	8.98	12.13	13.52	31	33.58
F_3 = N: P_2O_5: K_2O :: 160:80:80 kg/ha	36.63	38.65	3.76	4.72	9.47	9.99	13.23	14.70	28	31.95
S. Em ($\pm$)	0.70	0.75	0.08	0.10	0.18	0.19	0.26	0.29	0.6	0.70
CD (P=0.05)	2.09	2.23	0.24	0.29	0.54	0.57	0.78	0.86	1.9	2.10

from NPK fertility.Irrigation treatments though could not show significant effect on number of spikelets/ spike, irrigation schedule one showed certain improvement in this parameter. Increased fertility supplied to wheat crop produced correspondingly higher number of spikelets/spike probably due to more availability of nutrients from soil.

Since in irrigation schedule one there might be water deficit at flowering on heading stage which caused premature graindesiccation and resulted in marked decline in grain weight. Ahmed (1994) also reported similar effect.Increase in grain weight with increase in fertility could be due to grain filling owing to abundant supply of plant nutrient from applied nutrients (Singh, 1999).Irrigation schedule with one might have resulted in better maintenance of cell turgidity, greateravailability of nutrients and translocation of photosynthates consequently leading to good plant growth, yield attributes and high grain yield in wheat crop (Pal *et al,* 2001). The higher grain yield of wheat with higher level of NPK fertility was owing to significant and appreciable improvement in yield attributes and finally yield on account of adequate availability of nutrients (Sawarkar and Goydani, 1996).

The increased straw yield under four irrigation with schedule one might be attributed to be due to efficient physiological and metabolic processes resulting in luxuriant vegetative growth. (Richards and Wadleigh, 1952). The increased straw yield under higher level of fertility might be accounted for increased manufacture of carbohydrates (Watson *etal*, 1963). Increased biological yield under with irrigation schedule one might be attributable to be on account of efficient metallic activities with luxuriant plant growth leading to well developed “sink strength’’ ultimately enhanced the biological yield. (Poostchi, *et al*. 1972) Increased biological yield under higher rate of fertility might be assumed to be due to production of large dry matter and intensive growth.

Marginal improvement in harvest index (HI) in irrigation schedule one might be attributed to be on account of efficient metabolic activities with luxuriant growth leading to well-developed “sink strength’’ that finally increased harvest index. Reduced harvest index under all the fertilizer treatments was primarily due to non-proportional increase in economic yield with corresponding biological yield. The increase in supply of irrigation water at critical stages in schedule one provided adequate moisture in soil with played important role in nutrient uptake (Sharma *et al.*, 2007).Higher uptake of NPK nutrients under higher fertility level was mainly due to the fact that the better nutrient utilization by more healthy and vigorous plants under higher level resulting in enhanced nutrient absorption and uptake. (Auti, *etal.* 1999).

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Studies on Peanut Genotypes for Yield and other Ancillary Characters and their Suitability in West Bengal Under Changing Climatic Scenario

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Abstract

Peanut or Groundnut, is a multi- season legume as well as oilseed crop. In West Bengal, major growing season is rabi-spring with an area of 66.8 thousand hectare out of a total area of 77.8 thousand hectare. To find out potential genotypes of peanut for the rabi-spring season to enhance the yield and yield attributing characters under changing climatic scenario, a field experiment was conducted in Randomized Complete Block Design with four replications during 2023 rabi-summer crop season at Research Farm of Pulses and Oilseeds Research Station, Berhampore, Murshidabad under the Department of Agriculture, Government of West Bengal. A total of 17 genotypes of Spanish habit group were sown in gross plot size of 5.00m x 1.50m with a spacing of 30cm row to row and 10cm plant to plant. Recommended dose of Fertilizers (N: P_2O_5: K_2O @ 20:60:60 kg/ha) were applied in all the plots. Gypsum was applied @ 400 kg/ha by the side of the plants at 35 DAS. Standard agronomic practices were followed for raising good crops. It was found that TG 37A recorded highest pod yield of 2979 kg/ha followed by TG 51 (2906 kg/ha), Dh302 (2888 kg/ha) and Dh 303 (2823 kg/ha). The genotype Dh 303 recorded highest oil content i.e. 52% with a oil yield of 1093.56kg/ha. It can be concluded from this study that TG 37A, TG 51, Dh 302 and Dh 303 were the most suitable peanut genotypes in West Bengal under changing climatic scenario. Area enhancement of these genotypes certainly accelerate the edible oil production of this state as well as possibility for development of peanut based small scale cottage industry that ultimately leads to socio economic development of the nation.

Keywords: Peanut, Groundnut genotypes, Spanish, Spring season, Changing climate, Edible oil, West Bengal.

Introduction

Peanut (*Arachis hypogaea*) popularly known as Groundnut, is one of the most important oilseed crop in West Bengal. It is cultivated in different season but the major growing season is rabi-spring and sowing window open from mid November to end of February and sometime extended up-to first fortnight of March immediate after harvesting of potato and mustard crop. West Bengal has a total area of 77.8 thousand hectare out of which 66.8 thousand hectare (>85%) were cultivated in spring season with an average yield of 2561kg/ha.

Peanut seed has several uses; oil extracted from its seeds is used for cooking purpose (*Kudama, 2013; Arioglu et al., 2018*). The remaining seed cake after oil extraction is used as feed for livestock. The extracted peanut oil after decolonization and deodorization is used for making vegetable butter i.e. margarine (*Ahmadi and Shahmir, 2016*). Its seeds after removing the outer seed covering are used to decorate the vegetable dishes. Peanut seeds are also used in bakery products (e.g. nimko mix) and after roasting used for serving the guests in homes along with other dry fruits.

Worldwide production is concentrated in Asia (southern, eastern, and south-eastern part) and Africa (western part) where 94.6% of total harvested areas and 88.7% of total peanut production is located. The production sites are mostly in developing countries with semi-arid conditions where it mostly grown under rain fed conditions. In those continents, low and irregular precipitation is common to occur, and therefore prolonged dry condition especially during later parts of the peanut growth phase is the main constraint for low pod yield [*Nigam S 2014*]. It is relatively tolerant to drought and other abiotic stresses. Despite of drought tolerant, its pod yield are influenced by the availability of soil moisture especially during the critical growth phase. Peanuts grown with soil moisture available lower than field capacity along the growing season ultimately had low pod yield and its attributing characters compared to those obtained by well-watered crops [*Nassar et al, 2018 & Shrief et al, 2020*]. Drought stress also affected morphological traits i.e. reducing plant height, root and shoot dry weights [*Rani et al 2019*].

In view of the above, the present study was undertaken to find out potential genotypes of groundnut for the spring season to enhance the pod yield as well as oil yield under changing climatic scenario. We also study different ancillary characters of the test genotypes and their role to capture the mind of groundnut growers in this state.

Materials and Methods

A field experiment on Peanut genotypes of Spanish habit group was conducted in Randomized Complete Block Design with four replications during spring 2023 crop season at Research Farm of Pulses and Oilseeds Research Station, Berhampore, Murshidabad under the Department of Agriculture, Government of West Bengal. A total of 17 genotypes were sown in gross plot size of 5.00m x 1.50m with a spacing of 30cm row to row and 10cm plant to plant. Recommended dose of fertilizers (N: P2O5: K2O @ 20:60:60 kg/ha) were applied in all the plots. Gypsum was applied @ 400 kg/ha by the side of the plants at 35 DAS. Standard agronomic practices were followed for raising good crops. All data were taken from the entire net plot (4.80m x 0.900m) of each genotype from the experiment.

Data of experiments were analyzed according to the procedure of Randomized Complete Block Design *(Steel and Torrie, 1984*) and SPSS software programme was used to perform the analysis.

Results and Discussions

The results of yield and yield attributing character of Peanut genotypes under study are presented in Table-I. All the 17 genotypes are under Spanish habit group. Parameter wise findings and observations under changing climatic scenario are discussed below-

Plant Stand:

Plant stand is one of the most important and basic parameter for all crops to get potential yield. Out of the 17 peanut genotypes under testing in West Bengal condition, almost all the genotypes able to show good crop stand in the field. TG 37A shows highest plant stand (291000/ha) followed by TG 51(279000/ha). In Table 1, It is clearly indicate that the highest pod yield was recorded by the genotype TG 37A (2979kg/ha) followed by TG 51(2906kg/ha). In this experiment, the direct relationship between plant stand and pod yield was established like other crops also.

Pod and Haulm Yield:

Pod is the most important economic part of peanut crop. Haulm is also important in peanut cultivation as it is used as animal fooder. In the present investigation, it was found that TG 37A genotype recorded significantly highest pod yield i.e. 2979kg/ha followed by TG 51 (2906kg/ha) as compared to the genotype TAG 24, predominantly cultivated in West Bengal. In the same way, TG 51 (4622kg/ha) was recorded significantly highest haulm yield followed by TG 37A (4411kg/ha) compared to the genotype TAG 24. (Table 1).

TABLE 1. Results of peanut genotypes for yieldand other parameters during Spring 2023 crop season

Sl.No.	Genotypes	Plant Stand (000/ha)	Haulms	Yield (Kg/ha) Pods	Kernel	100 kernel wt (g)	SMK %	Oil %	Protein %
1	**TAG 24**	272	3843	2550	1836	44.25	94	49	32
2	**TG 91**	267	3819	2698	1997	44.68	96	49	32
3	**Dh 86**	244	3797	2545	1769	41.83	92	48	33
4	**OGIC 17-2**	246	3513	2429	1810	38.31	88	47	**34**
5	**UG-IC 214**	234	3325	2147	1374	36.71	85	49	32
6	**TCGS 2233**	275	3954	**2744**	2003	44.32	94	49	31
7	**TCGS 1785**	258	3806	2656	1886	38.80	89	49	32
8	**Dh 302**	284	3989	**2888**	2050	36.33	92	49	31
9	**TG 37A**	291	**4411**	**2979**	2190	44.97	95	45	**35**
10	**Dh 303**	276	3961	**2823**	2103	31.86	89	**52**	28
11	**TCGS 2038**	236	3467	2240	1624	45.03	91	48	33
12	**TCGS 1792**	268	3821	2406	1768	41.10	93	49	32
13	**TCGS 2333**	253	3723	**2749**	2048	44.52	92	49	31
14	**TCGS 2055**	231	3453	2365	1750	49.05	96	48	32
15	**TG 51**	279	**4622**	**2906**	2150	44.30	93	47	**34**
16	**PBS 14088**	261	**4062**	**2720**	1958	39.92	90	48	33
17	**J 117**	266	**4126**	**2707**	1813	36.37	91	**51**	30
	SE(m)±	**6.3**	**173.2**	**177.1**	**132.1**	**1.19**			
	CD(P=0.05)	**12.6**	**494.7**	**351.2**	**265.7**	**3.40**			
	CV%	**3.4**	**11.46**	**9.6**	**9.89**	**6.22**			

Maturity Period, Oil and Protein Percentage:

Duration is one of the most important parameter for accomodating any crop in the cropping system. In that aspect, peanut is most suitable crop to fit in the cropping system in West Bengal. The maturity duration of peanut crop is around 100-120 days. Peanut genotypes under study show that almost all were the same maturity duration range and thus easily accommodate in the cropping system. Rapeseed mustard and sesame are the main copetitive oilseed crops grown during rabi-summer season in West Bengal. It is clearly indicate that oil percentage of peanut is always higher than those other oilseed crops. In this experiment, the oil percentage recorded in the range of 47- 52 (Fig-1). The genotype Dh 303 recorded highest oil content i.e. 52% with a oil yield of 1093.56kg/ha. In addition to oil, peanut is also rich in protein. The protein content of the genotypes under study recorded 28-35 percent, which is much higher than any other oilseed crops.

Shelling and SMK Percentage:

Shelling and SMK percentage is very important for peanut growers as well as industry perspective. In Figure 2, the genotypes shows better shelling percentage and SMK percentage and it is around 72-74 and 92-96 respectively. Thus, such types of peanut genotypes are highly acceptable by the industry.

Conclusion

It can be concluded from this study that TG 37A, TG 51, Dh 302 and Dh 303 were the most

Fig. 1 Genotype wise maturity perid, oil and protein percentage

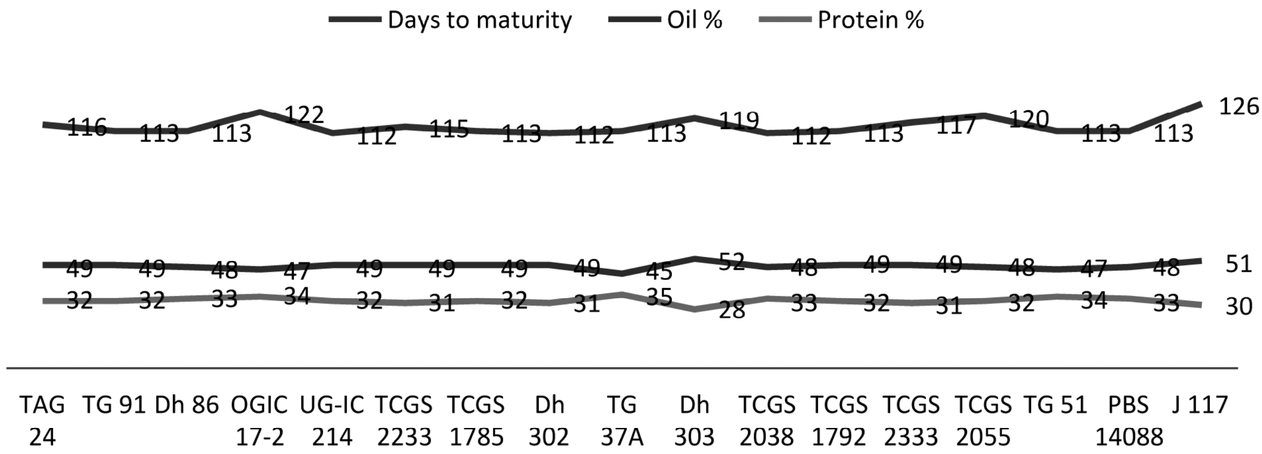
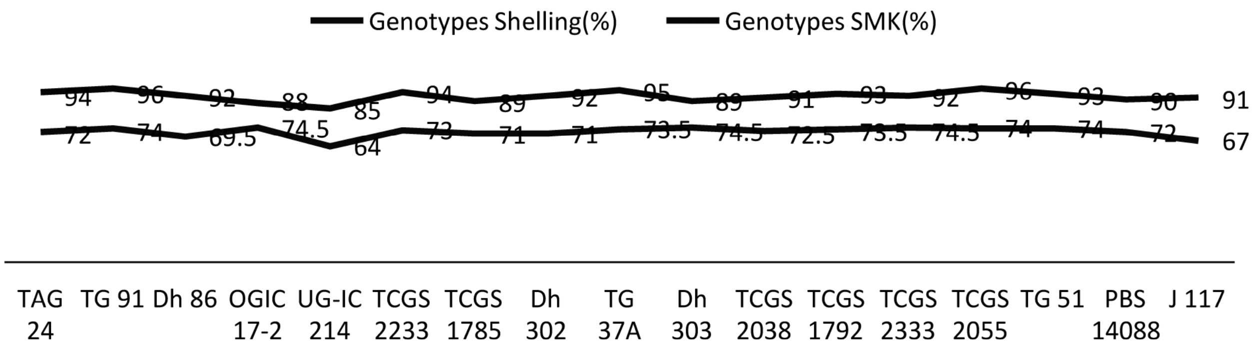


Fig. 2 Genotype wise Shelling and SMK(Sound Matured Kernel) Percentage



suitable peanut genotypes for pod and oil yield in West Bengal under changing climatic scenario. Area enhancement of these genotypes certainly accelerate the edible oil production of this state as well as possibility for development of peanut based small scale cottage industry that ultimately leads to socio economic development of the nation.

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Unveiling the Impact of Tillage and Weed Management Practices on Direct Seeded *Kharif* Rice (*Oryza sativa* L.) Under the Coastal and Saline Belt of West Bengal, India

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Abstract

The experiment was carried out on *Kharif* Season 2022 at Instructional Farm, Sasya Shyamala Krishi Vigyan Kendra, Ramakrishna Mission Vivekananda Educational and Research Institute, Arapanch, Sonarpur, Kolkata- 700150, South 24 Parganas, West Bengal in split-plot design with two main plots and six sub-plots and a total of twelve (12) treatment combinations each replicated thrice.The experiment comprised of two tillage practices *i.e.* zero tillage and conventional tillage as the main plot factor, as well as six weed management practices*i.e.* growing sesbania with rice followed by application of 2,4-D 1000 g *a.i.* ha^{-1}, pre-emergence application of pendimethalin 1000 g *a.i.* ha^{-1}, pendimethalin 1000 g *a.i.* ha^{-1} followed by one-hand weeding at 30 DAS, pendimethalin 1000 g *a.i.*ha^{-1} followed by Na-bispyribac 25 g *a.i.* ha^{-1} , weed-free and weedy check as a sub-plot factor. The experimental data related to each character of crop and weed were analysed statistically by the technique of "Analysis of variance" and significance was tested by variance ratio *i.e.* value at 5% level of significance. The experimental findings revealed that Conventional tillage (M_1) recorded more growth and yield attributes as well as a higher grain yield of rice than zero tillage practices (M_2). From the six subplot treatments weed free plots *i.e.* three-hand weeding at 20, 40, and 60 DAS (S_2) was found to be better in terms of weed control and grain yield, higher plant height, tiller $hill^{-1}$ and B:C ratio than other weed management practices which was statistically at par with pendimethalin 1000 g *a.i.* ha^{-1} followed by one-hand weeding at 30 DAS (S_5). Growing sesbania with rice followed by application of 2,4-D 1000 g *a.i.* ha^{-1} (Brown manuring) (S_3) recorded the higher grain yield and weed control efficiency than the solo application of pendimethalin (S_4) and pendimethalin 1000 g *a.i.* ha^{-1}*fb* Na-bispyribac 25 g *a.i.* ha^{-1} (S_6). As a treatment combination Pre-emergence application of pendimethalin 1000 g *a.i.* ha^{-1} *fb*one-hand weeding at 30 DAS in combination with conventional tillage (M_1S_5) was found to be ideal weed management practice for improving the rice grain yield by eliminating crop-weed competition in direct-seeded rice.

Keywords: *Coastal and saline belt, direct seeded kharif rice, tillage, weed management practices*

Introduction

Rice (*Oryza sativa* L.) is one of the foremost cultivated grain crops (cereal) throughout the world in terms of area and production after wheat and globally, more than half of the human population's livelihood is inextricably linked to rice for their rational needs (Ashraf *et al.*, 2006). In India rice is grown under miscellaneous soil, climate, and land situation, for this reason, the productivity of rice is low compared to many other countries in the world. Furthermore, nearly 90% of rice cultivation is generally done by marginal, small, and medium farmers, which is the core reason for decreasing rice productivity.

From ancient times rice is predominantly cultivated as a transplanting method of rice cultivation (Anaerobic). Traditionally rice is cultivated through transplanting utilizing manual planting of 25 to 40 days aged seedlings into the puddled soil. Since, the rice has been cultivated through the transplanting method by tradition, due to several factors it has some disadvantages also for the upcoming growing condition. Repeated puddling of land in the transplanting method has been encouraging tremendous complications such as destroying the soil's physical properties and disintegrating the soil aggregates, which means creating hard pans (Sharma *et al.*,2003).

Thereby, the direct seeded rice cultivation method seems the only feasible substitute to overcome these problems in the transplanting method (Tripathi *et al.*, 2004). In direct-seeded rice, the crop partially matures 7-10 days earlier than conventional transplanting rice which encourages the timely sowing of succeeding crops. Direct seeded rice method possesses many advantages in terms of cost of cultivation and management practices by eliminating the transplanting phase of rice seedlings and puddling, avoiding the stagnation of water throughout the crop growth stages in the field. Direct seeding of rice could reduce the labor requirement by up to 11-66% by rejecting the repeated tillage operations and transplanting of seedlings.

Nevertheless, weeds cause a tremendous reduction in production by up to 80% in the case of direct-seeded aerobic rice (Mahajan *et al.*, 2009). The majority of weed infestation depends on the methods of raising crops, the intensity of weeds, and competition with the crops at different stages. Weed causes yield reduction to the tune of 15-20% in anaerobic transplanted rice, 30-35% in an anaerobic direct seeded puddle, and more than 50% in the case of aerobic direct seeded upland rice. Weeds are generally controlled by manual hand weeding which is easy and effective in the case of direct-seeded rice. Despite several advantages, manual hand weeding is a very time-consuming and labor-intensive method. One of the major difficulties in hand weeding at younger growth stages is distinguishing the similarities between grassy weeds and rice seedlings. Therefore, weed control only using manual hand weeding is not economically sound and practical for the farmers.

Brown manuring practices can be a viable option in limiting weed infestation, suppressing the weed biomass, improving the soil ecosystem by adding organic matter and consequently increasing the crop yield. In the Brown Manuring process, sesbania and rice plants are co-cultured together in direct-seeded rice before, after, or as a mixed crop with rice and allowed to grow before the plant poses a woody stem. When the plant attains a reasonable height of 30-40 cm tall after 25-30 DAS, it is killed with 2,4-D ester @ 500 g ha^{-1} (Singh *et al.*, 2017). This brown manuring practice lessens approximately half of the weed population without creating any threat to the cash crop. Besides the weed-suppressing ability, sesbania co-culture has other benefits including the addition of atmospheric nitrogen and other recycled nutrients into the soil (Gopal *et al.*, 2010).

With these perspectives the above said programme has been proposed to conduct with the objectives*viz.* to study the effect of tillage management and different weed management practices on weed parameters, crop growth and yield of rice, to study the interaction effect of tillage practices with weed management practices on the weed control and productivity of DSR and to determine the rice cultivation's economic viability.

Materials and Methods

The present investigation was conducted at the Instructional Farm, Sasya Shyamala Krishi Vigyan Kendra, Arapanch, Sonarpur, South-24 Parganas, West Bengal during *kharif* (rainy) season of the year 2022. The soil of experimental soil was clay loam in texture having medium to low fertility with acidic reaction. The field experiment was carried out in split-plot design with two main plots and six sub plots.The experiment comprised of two tillage practices *i.e.* zero tillage and conventional tillage as the main plot factor, as well as six weed management practices*i.e.* growing sesbania with rice followed by application of 2,4-D 1000 g *a.i.* ha^{-1}, pre-emergence application of pendimethalin 1000 g *a.i.* ha^{-1}, pendimethalin 1000 g *a.i.* ha^{-1} followed by one-hand weeding at 30 DAS, pendimethalin 1000 g *a.i.*ha^{-1} followed by Na-bispyribac 25 g *a.i.*

TABLE 1. Effect of tillage and weed management practices on Plant height, Dry weight (g m^{-2})and tillers per hills

Treatments	Plant height (cm)			Dry weight (g m^{-2})			Tillers $hill^{-1}$		
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS
Tillage									
M_1	41.41	53.00	105.78	617.68	831.39	1019.51	6.04	12.46	11.33
M_2	46.23	63.78	113.17	767.14	970.07	1154.04	6.10	13.32	12.93
S. Em (±)	0.38	0.20	0.52	11.07	3.34	21.44	0.50	1.13	0.76
CD at 5%	2.31	1.22	3.18	67.35	20.34	130.47	3.05	6.85	4.64
CV (%)	13.68	11.46	12.02	3.37	5.79	4.18	17.51	18.54	13.35
Weed management practices									
S_1	38.27	56.03	102.20	668.93	827.87	1014.90	4.80	10.10	9.20
S_2	48.83	60.40	120.37	767.34	1025.65	1218.58	7.27	16.00	14.30
S_3	42.73	56.13	111.18	709.78	919.95	1042.81	5.83	12.18	12.80
S_4	44.50	59.03	103.17	617.10	830.19	956.59	5.67	10.88	10.77
S_5	46.30	58.70	115.33	761.63	948.77	1140.89	6.90	15.75	14.20
S_6	42.10	60.03	104.58	629.68	851.95	1146.90	5.97	12.42	11.50
S. Em (±)	2.13	1.49	2.76	14.60	22.15	30.76	0.40	0.82	0.73
CD at 5%	6.30	4.40	8.13	43.06	65.35	90.75	1.19	2.42	2.14
CV (%)	11.93	6.25	6.17	2.58	3.01	3.47	8.16	7.80	7.33

ha^{-1} , weed-free and weedy check as a sub-plot factor. in plots and six subplots and a total of 12 treatment combinations each replicated thrice. Rice variety Shatabdi(*IET 4786*) was taken for the experiment. Recommended dose of plant nutrients (viz. nitrogen, phosphorus, and potash) for rice were given through urea, single super phosphate, and muriate of potash, respectively. The recommended fertilizer dose was 60:40:40 kg N: P: K ha-1. Half dose of N and full dose of P and K were applied as basal at the time of final land preparation. ¼ of the N is applied at 25 DAT and rest ¼ is applied at 50 DAT. The observations for various growth attributes at different stages of crop growth, yield components and yield at harvest were recorded from the area earmarked in each plot. The experimental data related to each character of crop and weed were analysed statistically by the technique of "Analysis of variance" and significance was tested by variance ratio *i.e.* value at 5% level of significance.

Results and Discussion

The predominant weed flora found under the study area were *Echinochloacolona, Panicumrepens, Cynodondactylon* among the grasses, *Alternant herasessilis, Physalis minima, Abutilon indicum* among the broad leaved weeds and *Cyperusesculentus* and *Cyperusrotundus*among the sedges.

Among the different herbicidal treatment applications of pendimethalin @ 1000 g *a.i.* ha^{-1} + one hand weeding at 30 DAS recorded the maximum number of tillers per hill followed by growing sesbania with paddy + application of 2,4-D @ 1000 g *a.i.* ha^{-1} among all herbicidal treatments. However, the

TABLE 2. Effect of tillage and weed management practices on yield, harvest index and seed weight of rice

Treatments	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)	Seed Weight (g)
Tillage				
M_1	3120.18	4677.52	39.93	2.80
M_2	3631.34	5281.77	40.98	2.85
S. Em (±)	78.39	99.13	0.63	0.28
CD at 5%	477.05	603.27	3.80	1.65
CV (%)	7.00	7.06	3.55	7.43
Weed management practices				
S_1	2928.76	4469.78	39.52	2.79
S_2	3847.10	5792.44	41.17	2.85
S_3	3337.64	4894.09	40.62	2.80
S_4	3193.19	4568.81	40.12	2.79
S_5	3632.31	5450.87	40.98	2.84
S_6	3315.57	4701.89	40.35	2.81
S. Em (±)	87.60	163.00	1.36	0.36
CD at 5%	258.42	480.86	NS	2.12
CV (%)	4.52	6.70	-	9.31

number of tillers per hill was maximum under weeding thrice at all stages of observation, and minimum was under weedy check plots.

Pendimethalin @ 1000 g *a.i.* ha^{-1} + one hand weeding at 30 DAS increased growth attributes such as plant height, number of tillers per hill, dry matter accumulation m^{-2}.

Application of pendimethalin @ 1000 g a.i. ha^{-1} + one hand weeding at 30 DAS recorded the maximum grain yield and straw yield followed by growing sesbania with paddy + application of 2,4-D @ 1000 g *a.i.* ha^{-1} among all herbicidal treatments. The highest number of grain yield was noted under hand weeding thrice at 20, 40, and 60 DAS which was appreciably superior over all the herbicidal treatments.Among all the treatments, a minimum number of straw yields were recorded under weedy check.

The gross return was significantly influenced by different treatments, which ultimately differ the net return and B:C ratio. The highest yield of crops was noted under hand weeding plot thrice at 20, 40 and 60 DAS. But this treatment is not economically sound due to additional expenditure on hand weeding. This is not feasible to the farmers due to high investment and unavailability of labors.

In these findings the maximum and minimum cost of cultivation and net return were noted under hand weeded and weedy check plots. But the application of pendimethalin @ 1000 g *a.i.* ha^{-1} + one hand weeding at 30 DAS recorded highest net return and the benefit cost ratio.

Among the main plot treatment, the highest reduction in weed density was reported under conventional tillage. Data indicates that the different weed control treatments gradually reduced the density of all these weeds at 60 DAS. Maximum density was reported under weedy check.

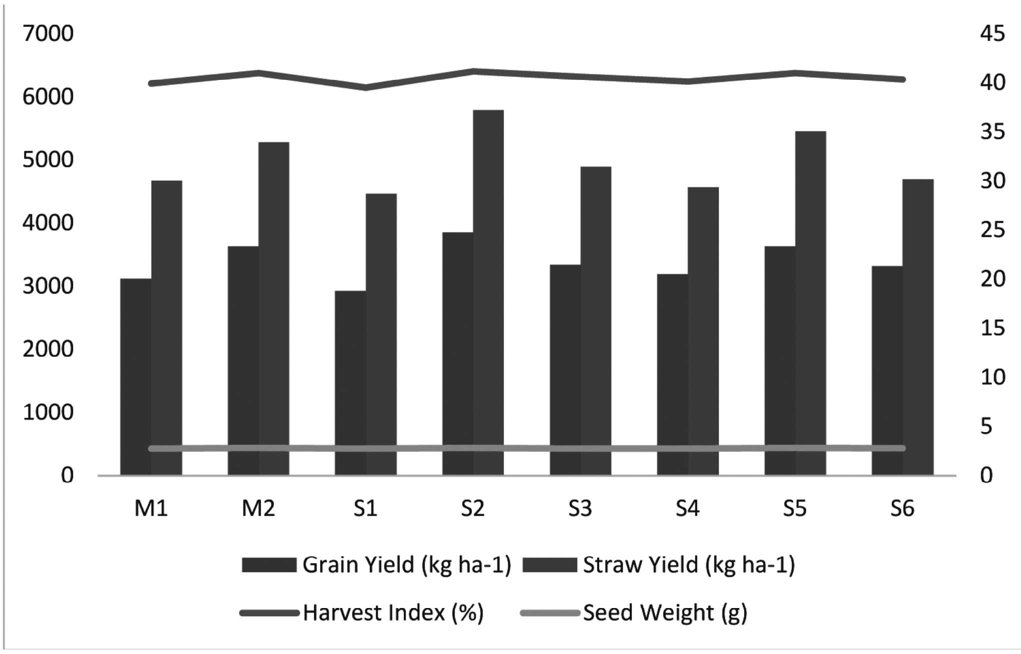

Fig. 1 Figure on the effect of tillage and weed management practices on yield, harvest index and seed weight of rice

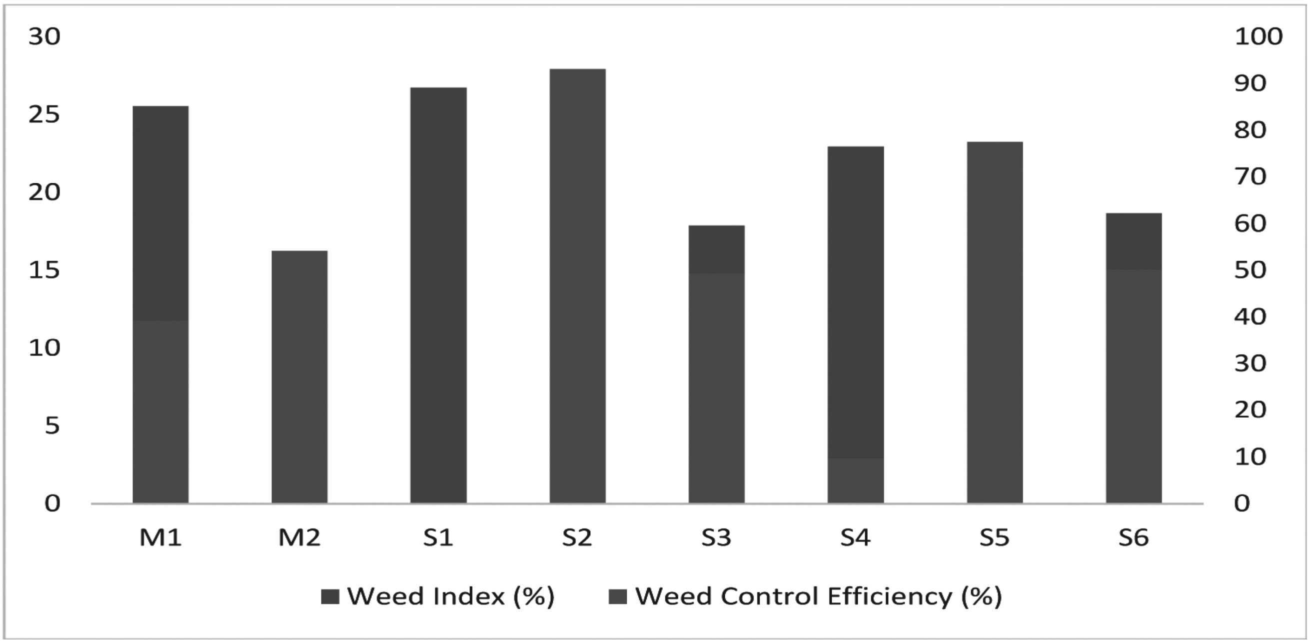

Fig. 2 Effect of tillage and weed management practices on weed index and weed control efficiency

Pendimethalin @ 1000 *a.i.* ha^{-1} + one hand weeding at 30 DAS showed maximum reduction in density of these weeds at 60 DAS followed by growing sesbania with paddy + 2,4-D @ 1000 *a.i.* ha^{-1}among all herbicidal weed management practices. The least density was observed under hand weeding thrice. It is obvious from the data that the dry weight of all these weeds was significantly reduced in conventional tillage over zero tillage plots. The data from the different treatments significantly reduced the weed dry weight at 60 DAS over weedy check plots. The dry weight of these weeds was maximum under a weedy check plot where no weed control measure was taken. But the reduction was more pronounced with the application of Pendimethalin @ 1000 *a.i.* ha^{-1} + one hand weeding at 30 DAS followed by growing sesbania with paddy + 2,4-D @ 1000 *a.i.* ha^{-1}among the all-herbicidal weed management practices. The lowest dry weight of these weeds was recorded under hand weeding thrice at 20, 40, and 60 DAS.

The data from different weed control treatments showed that weed index was minimum (0.00 %) with hand weeding thrice at 20, 40, and 60 DAS followed by Pendimethalin @ 1000 *a.i.* ha^{-1} + one hand weeding at 30 DAS (7.54 %) and growing sesbania with paddy + 2,4-D @ 1000 *a.i.* ha^{-1} (17.89 %) among the all-herbicidal weed management practices. The highest weed index was observed under (26.73 %) of weedy check plots. Among the tillage practices in mail plots, conventional showed the lowest weed index (7.58 %) over zero tillage (25.53 %).

The highest weed control efficiency was observed with the application of Pendimethalin @ 1000 *a.i.* ha^{-1} + one hand weeding at 30 DAS followed by growing sesbania with paddy + 2,4-D @ 1000 *a.i.* ha^{-1} (77.52 %) among the all-herbicidal weed management practices. However, hand weeding thrice at 20, 40, and 60 DAS, respectively was superior (93.18 %) amongst all weed control treatments in suppressing the weed growth. Among the tillage practices in mail plots, conventional showed the highest weed control efficiency (54.18 %) over zero tillage (39.19 %).

Conclusion

From the tillage practices, conventional tillage registered lower value of weed density and weed dry weight and higher value of growth and yield attributes and yield of crop. Weed Free plots recorded the highest value of all the growth, yield attributes, grain, and straw yield of rice. But this treatment does not economically perform well. However, application of pendimethalin @ 1000 g*a.i.* ha^{-1} followed by one hand weeding at 30 DAS significantly at per with weed free plot. Pendimethalin @ 1000 g *a.i.* ha^{-1} followed by one hand weeding at 30 DAS registered the lower value of weed density and dry weight of weed both at 60 and 90 DAS. Highest weed control efficiency was registered from the weed free plots, but both the treatments were at par with each other.The highest Gross returns, Net returns, and B: C ratio was observed from the plots where pendimethalin were applied @ 1000 g *a.i.* ha^{-1} followed by one hand weeding at 30 DAS.Thus, conventional tillage with application of pendimethalin @ 1000 g *a.i.* ha^{-1} followed by one hand weeding at 30 DAS was the best treatment combination for better weed management in Direct Seeded Rice.

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Weed Seed Bank Status- Indispensable for Annual Planning of Weed Pest Management to Increase Sustainable Crop Productivity

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Abstract

Sustainable system agriculture that modifies with keeping parity of human needs, is to be used with the available resources to solve our food, oil, nutrient, environment and health security. Ecosafe annual planning of weed pest management (APWPM) by reducing the weed seed bank prior to crop planting and further to reduce weed competition at CCWCP by using pre-emergence weed control measures can able to increase the production by around 10%. Weed seed bank status has played a vital role for APWPM. An initial pilot experiment was conducted at the viswavidyalaya farm, Mohanpur during 2010-2014 to study the weed seed bank status at 0-15 cm soil depth under aerobic (upland), anaerobic (medium lowland) on general cropping sequence and wasteland. To study the effect of conventional and conservation tillage and different integrated weed managements on weed seed bank variations at three different soil rhizosphere depths of 0-5 cm, 5-10 cm and 10-15 cm, further field experiment was conducted on rabi rapeseed cv. B-9 (Brassica campestris var. yellow sarson) – summer okra cv. Arka Anamika (Abelmoschus esculentus) – kharif rice cv. IET 4786 (Oryza sativa) during 2014-16 following split plot design replicated thrice. In pilot trial number of weed seeds in the anaerobic, aerobic and roadside ecosystem were 477, 308 and 390 %, respectively lesser in upper surface than the under surface of soil up to 0-15 cm depth. There is a gradual decrease of weed seed bank status over years following APWPM. In field experiments a decreasing trend in weed seed density at 0-15 cm under soil depth from initial (rabi 2014) to end of experiment (winter 2016) were observed in all three treatments of tillage practice. In zero till + Paraquat interact with PE chemical herbicide + POE MW, the maximum weed seed density is reduced. Increase in rice equivalent biological yield in 2016 over 2015 had maximum under PE botanical herbicide + MW (11.07%) followed by HW + MW (10.90%), PE chemical herbicide + MW (10.20%) and weedy check (9.55%). In a continuous culture of zero till with an application of non-selective contact paraquat dichloride applied @ 2 kg /ha just after harvesting and a week before sowing of next crop grown in sequence favoured the reducing of weed seed bank status and reduced the weed competition to crop, increased the crop growth and yield parameters and ultimately the crop biological yields with more NPV and better sustainable soil health. The weed seed bank status, in this inceptisol, plays a significant role in both conservation and conventional tillage systems to obtain a sustainable production by minimizing the weed pest loss following APWPM in all the crops grown in sequence.

Key words: Weed seed bank status, APWPM, Rice based crop sequence, sustainable yield

The concept of sustainable agriculture emphasizes on the conservation of the natural resources and maintains the quality of environment. Thus, Sustainable agriculture is the successful management of resources for agriculture to satisfy the changing human needs, while maintaining or enhancing the quality of environment and conserving the natural resources. In sustainable system agriculture resources are used properly and for that natural or ecosafe synthetic organic chemicals having very little harmful effect on the soil and the environment may be used while organic agriculture strictly avoids the use of any toxic chemicals like fertilizers and pesticides. Therefore, sustainable agriculture is a broad term that includes organic agriculture as well. India needs to produce 5–6 mt additional food grains/annum to meet the requirement

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of the burgeoning population. The concept of sustainable agriculture emphasizes on the conservation of the natural resources and maintains the quality of environment. Thus, Sustainable agriculture is the successful management of resources for agriculture to satisfy the changing human needs, while maintaining or enhancing the quality of environment and conserving the natural resources. In sustainable system agriculture resources are used properly and for that natural or ecosafe synthetic organic chemicals having very little harmful effect on the soil and the environment may be used while organic agriculture strictly avoids the use of any toxic chemicals like fertilizers and pesticides. Therefore, sustainable agriculture is a broad term that includes organic agriculture as well. India needs to produce 5–6 mt additional food grains/annum to meet the requirement of the burgeoning population. Rice-based cropping sequence is the most dominant crop sequence in West Bengal and play a crucial role in the food security of India with a system yield potential of 8.12 t /ha /year accounting for 23% of India's rice area. Eco-safe appropriate pest management can increase the production to the tune of additional 30 % and major pest weed along can surge 10.0 % additional production through annual planning of weed pest management (APWPM - two basic concepts are to diminish the weed seed bank prior to crop planting and further to reduce weed competition at CCWCP by using pre-emergence weed control measures) as it causes globally 11.5% and at national 10.9% production loss (Ghosh *et al.*, 2017). With changing climate, the weed biodiversity is also modificating and therefore, weed seed bank status has an immense importance for APWPM that takes the edge off the weed pest losses in crops grown in sequence for sustainable crop production in both conservation and conventional system agriculture.

Materials and Methods

An initial pilot trial in different crop fields each of aerobic (upland), anaerobic (medium lowland) and roadside including wasteland during 2010-14 and then field experiments during 2014-16 were conducted at the Viswavidyalaya farm, Mohanpur to study the weed seed bank status under APWPM at three different soil rhizosphere depths of 0-5 cm, 5-10 cm and 10-15 cm. In pilot trials general cropping sequence used at farm with recommended cultivation practice excepting weed management where APWPM was followed. In anaerobic situation kharif rice (Oryza sativa-cv MTU 7029 - boro rice (Oryza sativa-cv IET 4786) and aerobic situation pre-kharif black gram (Vigna mungo cv WBU 108) – kharif brinjal (Solanum melongana cv Pusa purple long) – rabi rapeseed (Brassica campestris cv B-9) cropping system was practiced. To study the effect of conventional and conservation tillage and different integrated weed managements on weed seed bank variations, field experiment was conducted with three main plots, T1–Conventional tillage; T2–Reduced tillage and T3–Zero Tillage + Paraquat dichloride @ 2 kg/ha and four sub-plots (W1–PE Chemical + POE Mechanical; W2–PE Botanical + POE Mechanical; W3–POE HW + POE Mechanical and W4–Weedy check) following split plot design replicated thrice on rabi rapeseed cv. B-9 (Brassica campestris var. yellow sarson) – summer okra cv. Arka Anamika (Abelmoschus esculentus) – kharif rice cv. IET 4786 (Oryza sativa) during 2014-16.

For weed seed bank analysis twenty samples were taken from individual plot for three different soil depths (0-5, 5-10 and 10-15 cm). The first sub sample was obtained at random in the plot and other sub samples were obtained by walking in zigzag fashion from the first sub sample location. Composite samples from each treatment were mixed into one per treatment in each pilot and field experiment and analyses of well mixed soil of 100 g was taken for an adequate representation of the entire soil core. Individual sample was washed through a fine mesh to remove soil particles. The remainder was air dried and then passed through a descending series of sieves. Whole seeds from each sieving were extracted by hand (removing the stones, non-seed particles) using the projector (document camera), identified (seeds, propagules, stolons, suckers, nuts etc.) and counted. Seed viability was determined by crushing the seed and inspecting the endosperm, with only those seeds exhibiting white healthy endosperm included in the counts. Number of weed seeds in soil before planting at 30 & 60 DAS and after harvesting of the crop per sample was worked out as per the FAO protocol (Forcella and Cardina,2016) for field experiment while only one-time during November first week for pilot experiment.

Balance nutrition was applied at recommended doses (5 t neem cake + N:P:K:: 60:30:30 kg/ha) as basal (full neem cake and phosphorus along with 25 % potash) and top dressing (25 % N at 10 DAS and rest N and K 25 % each at important physiological stages of these three crops grown in sequence). Required irrigations were provided only at important crop physiological stages and for insect and disease pest management ecosafe pesticide mixtures were used. The weed management practices were followed according to treatments in field experiment. Weed seed bank status in the crop field soil (both pilot and field), weed plant density and biomass, major crop growth and yield attributes, biological yield, soil micro-flora status and the net production value were recorded in the field experiment studies.

Results and Discussion

Pilot trial on anaerobic, aerobic and roadside ecosystem

In pilot trial number of mean weed seeds in the anaerobic, aerobic and roadside ecosystem were 477, 308 and 390 %, respectively lesser in upper surface than the under surface of soil up to 0-15 cm depth (Table 1). There is a gradual decline in the weed seed bank was observed in both cultivated plots (aerobic and anaerobic situation) and roadside plots from the initial year 2010 to final year 2014 of observation may be due to using the APWPM. Maximum mean weed seed density at under surface (0-15 cm) was observed at roadside ecosystem (643812 no. m-2) followed by aerobic (327911 no. m-2) and anaerobic (299334 no. m-2) and the corresponding figures of weed density in upper surface were 1653, 1064 and 628 no. m-2. A decreasing trend in weed seed density at 0 -5, 5 - 10 and 10 - 15 cm under soil depth was observed indicating the presence of weed seeds more in upper surface. In anaerobic situation these corresponding figures were 129778, 91556 and 78000 no. m-2; in aerobic situation 176889, 79,800 and 71, 222 no. m-2 and in roadside situation 516320, 95,367 and 32,125 no. m-2. The sedge weed propagules of Cyperus rotundus nut were mostly observed in the 10-15 cm soil layer. Higher weed seed population at upper layer of under soil surface is mainly due to deposition of weed seeds by natural phenomena from the existing weeds grown in these different situations. In anaerobic ecosystem where rice- rice crop sequence was followed, in lower depths (5 to 10 and 10 to 15 cm depth) puddling may helped to increase the weed seeds availability more than that of the aerobic situation where black gram- brinjal – rapeseed cropping sequence was followed. In roadside at 10-15 cm weed seed density was lowest because of the reason that as there is no ploughing the weed seeds at lowest level of observation (15 cm soil depth) may not be able to move at upper layer (0-5 cm) of under soil surface as happened in other two situations where cropping is continuing for years. Yenish et al, (1992) also showed similar opinion.

Field experiment on rice-based crop sequence

Weed seed bank

The field experimental results revealed that weed seeds at initial stage were counted from different depths

TABLE 1. Weed seed bank status under APWPM in pilot trial during 2010-14

Location of weed seeds	Mean weed seed density (number m-2)		
	Anaerobic	Aerobic	Roadside
Above surface	628	1064	1653
Under surface	299334	327911	643812
0-5 cm	129778	176889	516320
5-10 cm	91556	79800	95367
10-15 cm	78000	71222	32125

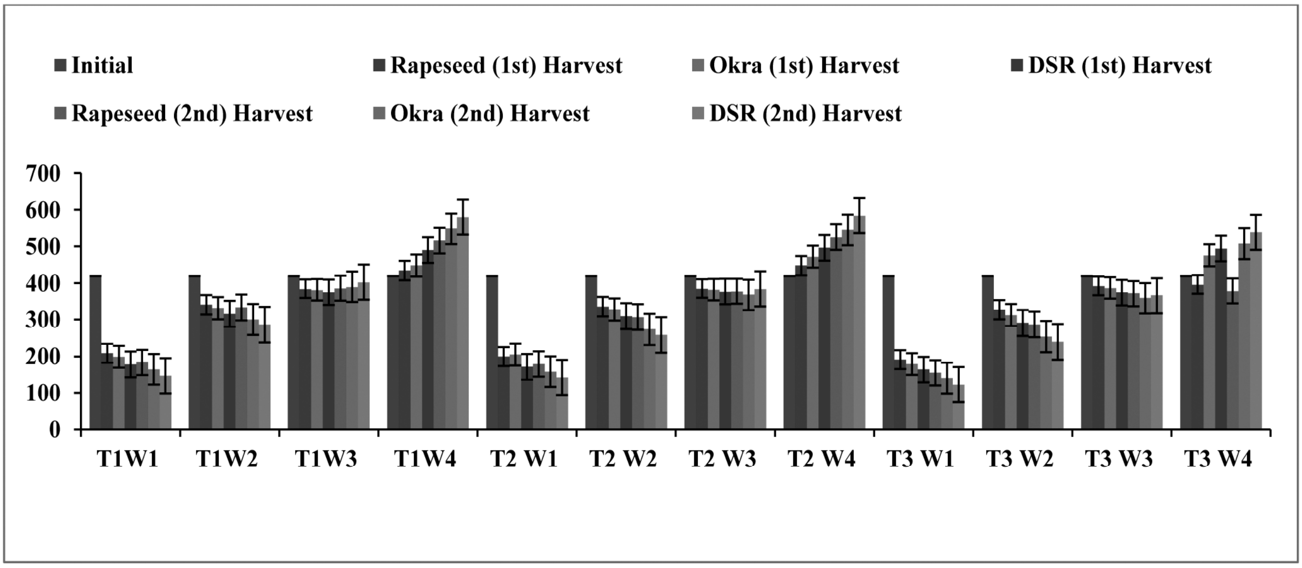
of under soil surface (250.67 seeds at a depth of 0-5 cm, 114.67 seeds at a depth of 5-10 cm and 54.33 seeds at a depth of 10-15 cm) and a total of 419.67 weed seeds / 100 g soil at 0-15 cm depth of under soil surface. A decreasing trend in weed seed density at 0-15 cm under soil depth from initial (rabi 2014) to end of experiment (winter 2016) were observed in all three treatments of tillage practice (Fig. 1). But, the per cent decrease of weed seeds was more prominent in Zero till + Paraquat (34.13%) over initial followed by reduced tillage (17.26%) and conventional practice (13.94%). While among the weed management practices, PE chemical + POE MW showed drastic reduction over initial (63.60%) in weed seed density followed by PE botanical + POE MW (29.18%) and POE HW + POE MW (7.78%) while the weedy check recorded an increase (17.53%) in weed seed bank density.

At the interaction level, there was a radical decrease in weed seed density at 0-15 cm soil depth from initial to end of experiment saving the tillage system and weedy check interaction. The decrease in weed seed density over initial was more prominent in Zero till + Paraquat f.b. PE chemical herbicide + POE MW (70.85%) followed by reduced (66.09 %) and conventional tillage (64.97%). PE botanical herbicide + POE MW recorded a reduction of weed seed density 42.97, 38.44 and 31.85% in zero till + paraquat, reduced and conventional tillage, respectively. In (Zero till + Paraquat) × (PE chemical herbicide + POE MW) interaction, the maximum weed seed density is reduced. Similar findings were recorded by Mohler *et al*, (2006) and Swanton *et al*, (2000) in Canada.

Weed density, biomass, WCE and WI

Both the weed density and dry biomass recorded lesser in the second year 2015-16 than that of first year 2014-15 in the rapeseed – okra – DSR cropping sequence at all the growth stages. Among the tillage treatments, the lowest weed density, lower most dry biomass and highest WCE at 20 and 50 DAS in both the years were recorded in conventional tillage in the rapeseed and okra crops followed by reduced and Zero tillage + Paraquat. While at harvest stage, the reverse trend prevailed i.e. in Zero tillage + Paraquat followed by conventional and reduced tillage in both rapeseed and okra. In case of the direct-seeded rice, the nethermost weed density, lowest dry biomass and highest WCE were obtained from Zero tillage + Paraquat followed by conventional and reduced till at

Fig. 1 Effect of different tillage systems and integrated weed management practices on total weed seed bank of Rapeseed – Okra – Direct-seeded Rice at 0-15 cm soil depth (No. per 100 g soil) during 2014-16



Main plots (Tillage practices): T1- Conventional tillage, T2-Reduced tillage and T3- Zero tillage; Sub plots (Weed management): W1 – PE Chemical herbicide +MW, W2- PE Botanical herbicide +MW, W3- HW + MW and W4- Weedy check

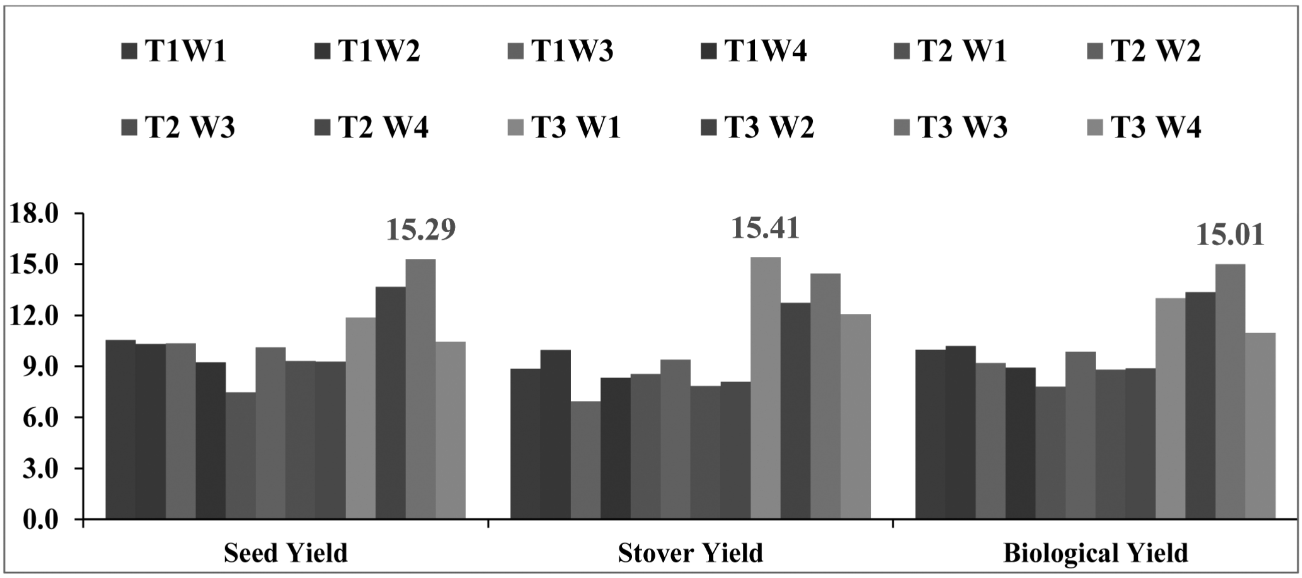
all the observations of three crop growth stages in both the years. Among the weed management treatments, as normally expected the weedy check recorded the highest weed density and dry biomass in all the crops at all the stages in both the years of experimentation. HW + MW recorded the lowest weed density and dry biomass as well as highest WCE in all the crops at all the growth stages of observations The lowest mean weed index (WI) value recorded the lowest of 6.96 and 3.20 in rapeseed and DSR crop, respectively in (Zero till + Paraquat) × (PE chemical herbicide + MW) while 2.17% in okra crop with the conventional tillage × (PE chemical herbicide + MW treatment). Vasileiadis et al, (2007) and Buhler et al, (1997) expressed similar opinion.

Biological yield and growth and yield parameters

The maximum mean value of various growth parameters viz. dry biomass, chlorophyll content, LAI, CGR and NAR of rabi rapeseed, summer okra and kharif DS rice were observed with conventional tillage × (PE chemical herbicide + MW) at 20 DAS in both the years; while at 50 DAS and at harvest, the maximum mean value of these growth parameters were noticed with HW + MW combined with conventional tillage

The rice equivalent seed/fruit and straw/ stover (biological) yield of rabi rapeseed – summer okra – kharif DS rice crops sequence (Fig. 2) showed that highest mean yield (24.99 and 12.42 t ha-1, respectively) was obtained under conventional tillage followed by reduced till (24.11 and 11.98 t ha-1, respectively) and zero till + paraquat (22.88 and 11.32 t ha-1, respectively). However, the increase in rice equivalent biological yield was obtained higher under Zero till + Paraquat (13.22%) followed by conventional (9.58%) and reduced (8.83%) tillage systems. Among the weed management treatments, the maximum mean seed and straw yield (26.92 and 13.53 t ha-1, respectively) was recorded in HW + MW followed by PE chemical herbicide + MW (25.90 and 12.65 t ha-1, respectively) and PE botanical herbicide + MW (23.31 and 11.68 t ha-1, respectively). But per cent increase in rice equivalent biological yield in second year over first year had maximum value under PE botanical herbicide + MW (11.07%) followed by HW + MW (10.90%), PE chemical herbicide + MW (10.20%) and weedy check (9.55%). Angiras et al (2010) working in India found similar results.

Fig. 2 Effect of different tillage systems and integrated weed management practices on seed, stover and biological yield of Rapeseed – Okra – Direct-seeded Rice at 0-15 cm soil depth during 2014-16



Main plots (Tillage practices): T1- Conventional tillage, T2-Reduced tillage and T3- Zero tillage; Sub plots (Weed management): W1 – PE Chemical herbicide +MW, W2- PE Botanical herbicide +MW, W3- HW + MW and W4- Weedy check

Soil microflora status

The results on soil microflora population (total fungi, bacteria and actinomycetes) revealed that at initial stage it was total fungi as 14.00 CFU × 104, total bacteria 128.00 CFU × 106 and total actinomycetes 173.00 CFU × 105. All the three tillage practices recorded increase in the soil microflora population from the initial to the end of the experimentation period but the per cent increase was more in case of Zero till + Paraquat while lowest in conventional tillage at all the observations (initial, 20 DAS and at harvest) in all the crops grown in sequence in both 2015 and 2016. Felix and Owen (2001) expressed similar view. Among the different weed management treatments, the weedy check plot recorded the maximum soil microflora population (total fungi, bacteria and actinomycetes) immediately followed by HW + MW, PE botanical herbicide + MW and PE chemical herbicide + MW at all the observations.

Production economics

The result on mean net return of the system REY revealed that the mean maximum net return was obtained from conventional tillage with PE chemical herbicide + MW (4,73,596) followed by reduced tillage combined with PE chemical herbicide + MW (4,66,609); conventional tillage combining with HW + MW (4,57,077); reduced tillage integrated with HW + MW (4,52,818); PE chemical herbicide + MW (4,44,202) and HW + MW (4,33,082) combining with Zero till + Paraquat. The mean maximum NPV of the system REY was obtained with Zero till + Paraquat combining with PE chemical herbicide + MW (6.01) followed by reduced tillage integrated with PE chemical herbicide + MW (5.63); conventional tillage combined with PE chemical herbicide + MW (5.00) and Zero till + Paraquat integrated with PE botanical herbicide + MW (4.99).

The economics (gross and net return and NPV) of the treatments used in this experiment conducted during 2014-16 (Table 2) clearly indicated that though in individual crop gross and net return showed a dominance of conventional tillage combining with PE chemical herbicide + MW or HW + MW but, still, the NPV is higher in Zero till + Paraquat when combining with PE chemical herbicide + MW. Even in REY the same integrated treatment recorded higher NPV followed by the other two reduced and conventional till treatments when combined with PE chemical herbicide + MW. Adhikary and Ghosh (2014) expressed similar opinion working at new alluvial zone of West Bengal.

Table 2. Net Production Value under different tillage and integrated weed management practices in rapeseed – okra – DS rice cropping sequence during 2014-16

	Cost of Cultivation			Gross Return			Net Return			NPV		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean	2014-15	2015-16	Mean	2014-15	2015-16	Mean
T1W1	94813	94813	94813	538180	598638	568409	443367	503825	473596	4.68	5.31	5.00
T1W2	98305	98305	98305	488900	543248	516074	390595	444943	417769	3.97	4.53	4.25
T1W3	130900	130900	130900	557400	618555	587977	426500	487655	457077	3.26	3.73	3.49
T1W4	89080	89080	89080	413820	455024	434422	324740	365944	345342	3.65	4.11	3.88
T2 W1	82813	82813	82813	527520	571323	549422	444707	488510	466609	5.37	5.90	5.63
T2 W2	86305	86305	86305	469320	520718	495019	383015	434413	408714	4.44	5.03	4.74
T2 W3	118900	118900	118900	544340	599095	571718	425440	480195	452818	3.58	4.04	3.81
T2 W4	77080	77080	77080	396560	436243	416401	319480	359163	339321	4.14	4.66	4.40
T3 W1	73933	73933	73933	486700	549569	518135	412767	475636	444202	5.58	6.43	6.01
T3 W2	77425	77425	77425	432400	495260	463830	354975	417835	386405	4.58	5.40	4.99
T3 W3	110020	110020	110020	502640	583566	543103	392620	473546	433083	3.57	4.30	3.94
T3 W4	68200	68200	68200	381940	425170	403555	313740	356970	335355	4.60	5.23	4.92

Main plots (Tillage practices): T1- Conventional tillage, T2-Reduced tillage and T3- Zero tillage; Sub plots (Weed management): W1 – PE Chemical herbicide +MW, W2- PE Botanical herbicide +MW, W3- HW + MW and W4- Weedy check

Conclusion

Therefore, following annual planning of weed pest management (APWPM) on the pilot trials in roadside and general cropping sequence, in anaerobic situation kharif rice - boro rice and aerobic situation pre-kharif black gram – kharif brinjal – rabi rapeseed the weed seed bank density is reduced over years and in field trials growing of rabi rapeseed – summer okra – kharif DS rice cropping sequence in up-medium land ecosystem showed that in a continuous culture of zero till with an application of non-selective contact paraquat dichloride applied @ 2 kg ha-1 just after harvesting and a week before sowing of next crop grown in sequence may favour the reducing of the weed seed bank status, minimizing the weed flora density reduces the weed competition to crop, increases the crop growth and yield parameters and ultimately the crop biological yields with more NPV and better sustainable soil health. The weed seed bank status, thus, plays a significant role in both conservation and conventional tillage systems to obtain a sustainable production by minimizing the weed pest loss following APWPM in all the crops grown in sequence.

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