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Effect of Herbicides on Growth and Yield of Zero Tilled Wheat (*Triticum aestivum*)

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Abstract

The Investigation designed to Study the effect of herbicides during winter season of 2020-21 and 2021-22 at the Water Management Research Station, Ranaghat, West Bengal with 12 treatments of herbicides showed certain positive effects of herbicides on growth and yield of wheat on zero tilled wheat. Results indicated that application of Pendimethalin + Metribuzin resulted lower weed population and lowest quantum of dry weight. Among the treatments mixture of Pendimethalin + Metribuzin showed the highest weed control efficiency in zero tilled wheat. The some treatment also showed the lowest persistence efficiency in weeds. Pendimethalin + Clodinafop Propargyl recorded higher leaf Area Index, Crop Growth Rate, Relative Growth Rate and Net assimilation Rate in wheat. Pendimethalin + Metribuzin recorded significantly highest number of ear head/m^2 in zero tilled wheat. Pendimethalin + Clodinafop Propargyl produced maximum number of spikelets/spike. Pendimethalin + Clodinafop resulted in maximum grain yield of wheat which was 159.39% higher over the control on pooled basis. However, mixture of Pendimethalin + Metribuzin recorded maximum straw yield.

Introduction

Zero tillage technology is gaining popularity in rice wheat system of Indo-gangetic plains of India, as this technology has not only reduced the incidence of problematic weed in wheat but also improved the input use efficiency (Mishra *et al.,* 2005). Effective weed control becomes of paramount significance in reduced tillage system. It is imperative to screen herbicides with alternate modes of action for effective weed control and to ensure better crop yield. It is essential to identify alternative herbicides molecules with broad spectrum activity for sustainable weed management in wheat. Hence the present investigation was undertaken to test the efficacy of some new germination herbicides along with widely used one 2, 4-D and other new generation herbicides in wheat.

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 on Gangatic alluvial land. The experiment consisting of 12 treatments viz. W_1- No weeding (Control); W_2- One hand weeding at 25 days(DAS) after sowing; W_3- Pendimethalin 30 EC @ 1.0 kg ai/ha, 2-3 DAS; W_4- Metsulfuron Methyl 20 WP @ 0.004 kg ai/ha, 25-30 DAS; W_5- Clodinafop Propargyl 15 WP @0.06 kg ai/ha, 25-30 DAS; W_6- Metribuzin 70 WP @0.30 kg ai/ha, 25-30 DAS; W_7- 2,4-D Sodium salt 80 WP @ 100 kg ai/ha, 25-30 DAS; W_8- Pendimethalin 30 EC @ 1.0 kg ai/ha, 2-3 DAS + One hand weeding at 25 DAS; W_9- Pendimethalin 30 EC @ 100 kg ai/ha, 2-3 DAS + Metsulfuron Methyl 20 WP @ 0.004 kg ai/ha, 25-30 DAS; W_{10}- Pendimethalin 30 EC @ 100 kg ai/ha, 2-3 DAS + Clodinafop Propargyl 15 WP @0.06 kg ai/ha, 25-30 DAS ; W_{11}- Pendimethalin 30 EC @ 100 kg ai/ha, 2-3 DAS + Mertibuzin 70 WP @0.30 kg ai/ha, 25-30 DAS; W_{12}- Pendimethalin 30 EC @ 100 kg ai/ha, 2-3 DAS + 2,4-D Sodium salt 80 WP @ 100 kg ai/ha, 25-30 DAS laid out in Randomized Block Design with three replications. Wheat CV UP- 262 was sown with seed rate of 100kg/ha with spacing of 20cm row distance in continuous spacing. The crop CV UP- 262 was sown by zero till seed cum fertilizer drill in unploughed land during third week of November in both the years. The crop was fertilized with 120kg N + 60 kg P_2O_5+ 60 kg K_2O /ha. The crop received five irrigations at critical stages of growth. The crop was harvested within first week of March in both the year.

Results and discussion

All the weed control treatments gave significant and appreciable reduction in weed population and dry weight of weeds as compared to weed cheek (Table 1). Lower weed density and weed biomass in combined application of Pendimethalin and metribuzin was due to their broad spectrum activity on established plants of both narrow and broad leaved weeds. (Pandey *etal.,* 2002). Weed control efficiency was maximum in Pendimethalin + Metribuzin probably because of Metribuzin combined with Pendimethalin at moderate dose might have acted synergistically in broadening the spectrum of weed control resulting in higher weed control efficiency. Poor efficiency of Metsulfuron methyl followed by 2, 4-D salt might be due to re-emergence of weeds at latter stage of crop growth due to their shorter persistence effect. Lowest weed persistence index was observed with the combination of Pendimethalin + Metribuzin which might be due to control of complex weed flora compared with sole application of Pendimethalin + Metribuzin (Reddy *et al.*2006). Pendimethalin + Clodinafop and Pendimethalin and supplements with hand weeding considerable increased leaf area index possibly due to better control of weeds and hence tilting the crop weed competition in favour of crop resulting in greater number and size of leaves which led to higher leaf area index. Higher crop growth rate (CGR) with Pendimethalin + Clodinafop and Pendimethalin with hand weeding might be due to higher leaf area index which accumulated dry matter at a faster rate per unit of leaf area per unit time by reducing death of tillers and senescence of leaves in wheat (McDonald *et al.,* 1984). Increase in relative growth rate with the use of 2, 4-D sodium salt was possibly due to restrict supply of growth resources on account of intense competition from weed growth under this treatment. Pendimethalin + Clodinafop exhibited higher net assimilation rate (NAR) which could be possibly due to higher crop growth rate. Higher NAR expresses plants capacity to increase dry weight in terms of area of its accumulating surface (Reddy,2000).

Maximum of tillers per m^2 was recorded under hand weeding probably due to effective

Table 1. Effect of herbicides on total population and total dry weight of weeds and total weed control efficiency of zero tilled wheat

Treatments	Total population of weeds/m^2 (at 75 DAS)		Total dry weight of weeds g//m^2 (at 90DAS)		Total weed control efficiency % (at 75 DAS)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
W1	1319.6	1290.0	234.09	230.58	0.0	0.0
W2	6 15.2	87.5	105.90	101.14	55.1	56.5
W3	831.3	802.2	152.85	147. 50	33.6	34.9
W4	1184.1	1179.9	199.55	198.85	12.0	11.0
W5	579.7	557.9	133.69	128.68	45.1	46.4
W6	318.7	313.9	91.24	89.87	63.8	63.8
W7	1051.5	1025.2	183.85	I 79.25	19.0	19.9
W8	676.2	666. 1	126.30	124.41	48.9	48.9
W9	993.5	953.9	157.94	151.65	29.5	31.3
W10	537.9	519.1	122.92	118.62	50.0	51.0
W11	202.6	195.5	57.21	55.21	77.4	77.8
W12	917.8	904.1	152.35	150.57	32.6	32.6
S. Em (±)	34.7	34.1	6.27	6.15	1.9	1.9
CD (P=0.05)	101.B	100.0	18.38	18.04	5.6	5.6

TABLE 2. Effect of herbicides on persistence index and physiological growth parameter of zero tilled wheat

Treatments	Persistence index at 75 DAS		Leaf Area Index (LAI) at 60DAS	
	2020-21	2021-22	2020-21	2021-22
W1	1.000	1.000	3.290	3.751
W2	0.211	0.198	4.500	5.175
W3	0.422	0.405	3.780	4.385
W4	0.795	0.814	4.163	4.746
W5	0.243	0.232	4.120	4.697
W6	0.088	0.088	4.563	5.430
W7	0.650	0.637	4.120	4.862
W8	0. 64	0.64	4.813	5.545
W9	0.535	0.508	4.090	4.744
W10	0.205	0.197	4.797	5.565
W11	0.035	0.034	4.080	4.702
W12	0.473	0.473	4.177	4.649
S. Em (±)	0.024	0.024	0.138	0.159
CD (P=0.05)	0.069	0.069	0.404	0.465

TABLE 3. Effect of herbicides on physiological growth parameter of zero tilled wheat

Treatments	Corp Growth Rate (CGR) (g/m²/ day) at 45- 60 DAS		Relative Rate (CGR) (g/g/ day) maximum at 45- 60 days		Net Assimilation Rate (NAR) (g/m²/ day) at 45-60 days	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
W1	9.681	11.036	0.078	0.078	3.159	3.159
W2	14.957	17.201	0.086	0.086	3.633	3.633
W3	11.133	12.915	0.079	0.079	3.222	3.222
W4	12.538	14.293	0.082	0.082	3.310	3.309
W5	14.333	16.340	0.087	0.087	3.797	3.797
W6	14.133	16.819	0.086	0.086	3.522	3.522
W7	12.668	14.948	0.084	0.084	3.464	3.464
W8	14.801	17.051	0.085	0.085	3.466	3.466
W9	12.103	14.040	0.081	0.051	3.274	3.274
W10	14.976	17.372	0.088	0.088	3.586	3.586
W11	12.268	14.138	0.082	0.082	3.327	3.327
W12	12.480	14.000	0.082	0.082	3.310	3.310
S. Em (±)	0.418	0.482	0.003	0.003	0.115	0.115
CD (P=0.05)	1.226	1.413	NS	NS	0.338	0.338

TABLE 4. Effect of herbicides on yield attributing characters of zero tilled wheat

Treatments	Tiller/m²		Spikes / m²		Length of spike (cm)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
W1	199.40	245.75	178.35	234.05	10.00	10.10
W2	418.17	525.85	379.05	478.04	9.60	9.12
W3	232.40	269.07	208.63	249.14	9.60	9.41
W4	352.35	390.74	318.67	365.18	9.60	9.74
W5	357.07	422.88	323.00	387.97	10.20	10.35
W6	369.32	427.18	334.24	393.71	10.20	10.30
W7	271.97	312.53	244.92	294.84	11.00	10.12
W8	352.53	437.00	318.84	399.09	11.60	10.44
W9	332.03	413.84	300.03	367.85	10.60	10.76
W10	328.32	348.07	296.63	322.29	10.60	10.76
W11	399.77	442.34	362.18	409.96	11.10	10.88
W12	222.21	260.70	199.28	241.39	11.50	10.93
S. Em (±)	9.59	11.12	8.643	10.33	0.37	0.36
CD (P=0.05)	28.12	32.61	25.348	30.29	1.10	1.05

control of all types of weed. Combined treatment of Pendimethalin + Metribuzin recorded maximum car head per m² possibly due to better weed control. Combined application of Pendimethalin + 2,4-D sodium salt, Pendimethalin and hand weeding and Pendimethalin + Metribuzin recorded grater length of spike due to better control of competing weeds with wheat crop. Pendimethalin + Clodinafop, Pendimethalin and hand weeding exhibited higher number of spikelets/ spike possibly due to poor resurgence and regrowth of weeds making them unable to compete with the crop plant for growth factors Clodinafop propargyl followed by Pendimethalin combined with Clodinafop propargyl resulted in higher 1000 grain weight due to comparatively lower weed dry weight and higher control efficiency in these treatments. Brar *et al.,* (2000) also reported positive effect of Clodinafop on enhancing 1000-grain weight of wheat crop.

Maximum grain yield under combined application of Pendimethalin + Clodinafop might be due to weed free conditions, which might have resulted in increased nutrients, water, space and light supply to wheat crop due to absence of crop weed competition. This in turn might have resulted in grater photosynthesis and hence better translocation of photosynthates besides larger sink and stronger reproductive phase as reflected in maximum expression of yield attributes and ultimately higher grain yield. Higher grain yield obtained under hand weeding was obviously due to cumulative effect of reduced weed competition and higher value of yield attributes. The lower yield under sole application of Pendimethalin, Metsulfuron methyl, 2,4-D sodium salt may be due to adverse effect on crop growth and most of the yield attributes. The crop weed competition greatly reduced the wheat yield under weedy check (Singh *et al.,* 2005). Combination of Pendimethalin + Metribuzin recorded the maximum straws yield followed by Pendimethalin + Clodinafop, Pendimethalin with hand weeding once resulted in significantly higher straw yield than other treatments possibly due to lower weed population and dry weight of weeds in these treatments. Higher biomass yield recorded under combined use of Pendimethalin + Clodinafop followed by Pendimethalin + Metsulfuron might be due to combined higher yield of grains and straw probably on account of clean

Table 5. Effect of herbicides on yield components and yield of w zero tilled wheat

Treatments	Number of Spikelets / Spike		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	2020-21	2021-22
W1	35.26	31.73	24.34	24.73	1.50	1.80	4.45	5.07	5.95	6.87	25.21	26.19
W2	36.89	35.05	27.73	28.17	3.80	4.48	6.05	6.96	9.85	11.44	38.58	39.19
W3	36.00	35.28	29.89	31.98	2.20	2.53	3.85	4.47	6.05	7.00	36.36	36.16
W4	36.62	37.17	21.86	23.17	2.50	2.93	6.00	6.84	8.50	9.77	29.41	29.95
W5	38.22	38.79	31.41	33.29	3.80	4.56	8.00	9.12	11.80	13.68	32.20	33.33
W6	36.82	37.19	29.02	31.34	3.50	4.13	7.00	7.70	10.50	11.83	33.33	34.91
W7	35.80	32.94	27.93	29.61	2.40	2.76	3.B5	4.54	6.25	7.30	38.40	37.79
W8	45.30	44.39	27.20	27.64	3.85	4.50	7.95	9.16	11.80	13.66	32.63	32.97
W9	38.45	39.03	23.44	24.61	2.65	3.18	6.36	7.38	9.01	10.56	29.41	30.12
W10	45.20	45.88	29.91	32.00	3.93	4.64	8.15	9.45	12.08	14.09	32.53	32.91
W11	36.41	36.77	27.47	29.12	3.55	4.08	8.52	9.82	12.07	13.90	29.41	29.37
W12	45.52	43.24	27.56	29.21	2.45	2.87	5.88	6.60	8.33	9.46	29.41	30.29
S. Em ($^{+}_{-}$)	1.34	1.29	0.93	0.98	0.212	0.097	0.20	0.23	0.30	0.34	1.05	1.07
CD (P=0.05)	3.92	3.79	2.73	2.86	0.623	0.284	0.60	0.69	0.87	1.00	3.07	3.13

cultivation with minimum weed crop competition resulting in better crop growth and reproductive growth of the crop. Higher harvest index under hand weeding is an indication of increased physiological capacity of to metabolize the photosynthates towards economic yield. The manual weeding has caused proportionately grater increase in economic part than in non-economic part which might have resulted in higher harvest index.

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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 Kendra, 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'-$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

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

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 corresponding development

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 (±)	1.08	1.66	1.46	0.03	0.04	0.04	0.57	0.48	0.62
CD at0.05%	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 (±)	0.53	0.62	0.58	0.05	0.68	0.09	0.26	0.54	0.24
CD at0.05%	1.64	1.88	1.86	NS	NS	NS	NS	NS	NS

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

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

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.

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

Treatments A Cropping system	2017-18 LER of Main Crop	LER Intercrop	Total LER	2018-19 LER of Main Crop	LER of of Intercrop	Total LER	Pooled LER of Main Crop	LER of Intercrop LER	Total
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 (±)			0.09			0.06			0.09
CD at0.05%			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 (±)**CD at0.05%**			0.07			0.054			0.06
			0.24			0.15			0.19

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

Treatments A Cropping system	2017-18 RCC of Main Crop	2017-18 RCC of intercrop	2017-18 Product Value (K)	2018-19 RCC of MainCrop	2018-19 RCC of intercrop	2018-19 Product Value (K)	Pooled RCC of Main Crop	Pooled RCC of intercrop	Pooled 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	2017-18				2018-19				Pooled			
A Cropping system	*Gross Cost (x1<tRs /ha)*	*Gross returns (x1<tRs /ha)*	*Net returns (x1<tRs /ha)*	*BC ratio*	*Gross Cost (x1<tRs /ha)*	*Gross returns (x1<tRs /ha)*	*Net returns (x1<tRs /ha)*	*BC ratio*	*Gross Cost (x1<tRs/ ha)*	*Gross x 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, $P_2 0_5$, $K_2 0$ 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	N Uptake						P Uptake						K Uptake					
A. Cropping	Main Crop			Inter-crop			Main Crop			Inter-crop			Main Crop			Inter-crop		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
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_20_5, K_20 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 A Cropping system	O C 2017-18	O C 2018-19	O C Pooled	N 2017-18	N 2018-19	N Pooled	p 2017-18	p 2018-19	p Pooled	K 2017-18	K 2018-19	K 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

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Estimation of Variability, Correlation and Path Analysis in Sesame (*Sesamum indicum* L.)

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Abstract

Sesame known to be the most ancient oilseed crop in the world and well recognized for good quality edible oil due its high PUFA content, antioxidant properties, excellent nutritional and medicinal properties. The present investigation aims at analyzing the variability among promising parents and newly developed genotypes of sesame on the basis of 8 morphological characters. Phenotypic coefficients of variation exhibited a bit higher values but maintained a close relation with genotypic variation and genotypic co-efficient of variation for all the traits, indicating low G×E interaction. A combination of high heritability (broad sense) and high genetic advance indicate preponderance of additive gene action which is fixable. Additive gene action was prominent for the traits like no of capsules/plant, seed yield /plant, and primary branches/plant. Path coefficient analysis indicated that number of capsules/plant exhibited highest positive direct effect on seed yield/plant followed by 1000 seed weight and plant height.

1. Introduction

Sesame (*Sesamum indicum* L.), known to be the most ancient oilseed crop in the world and well recognized for its excellent nutritional and medicinal properties is evidently domesticated in Indian subcontinent to its modern cultivated form.It was cultivated and domesticated on the Indian subcontinent during Harappan and Anatolian eras over 4,000 yrs ago. (Bedigian and Van der Mesen, 2003). Due to the great stability of its oil, easiness of extraction and resistance to draught. Sesame was a major oilseed crop in the ancient world. Sesame is so ancient that it is almost impossible to say with any degree of accuracy where and when this domestication took place and there is some disagreement on this point till today. Sesame is a highly drought tolerant crop and grows well in most kind of soils, regions and is also well suited to different crop rotations. Sesame has both nutritional and medicinal properties. Sesame seeds are an important source of oil (44 - 58%), protein (18 - 25%), and carbohydrates (13.5-18%) (Bedigian et al. 1986). They are used as active ingredients in antiseptics, bactericides, viricides, disinfectants, moth repellants, and antitubercular agents because they contain natural antioxidants such as sesamin, sesamol, and sesamolin (Bedigian 2010).Sesame oil has the highest antioxidant content (Anilakumar et al. 2010) and contains several fatty acids such as oleic acid (43%), linoleic acid (35%), palmitic acid (11%), and stearic acid (7%) (Hiremath et al. 2007). Sesame seed contains high levels of fat and protein. The chemical composition of sesame seed varies with the variety and also depends on the origin, color, and size of the seed. The fat content of sesame seed is around 40-50% whereas the protein content is around 20-30%.

Improvement of sesame production is still hampered due to lack of promising variety with high yield and oil content. Assessment of vriability is an initial step in breeding programme where large variability among potential parents is always desirable. Assessment of variation, correlation and path determine the characters which are related to yield. The present investigation was carried out to gather information on variability, heritability and genetic advance and to determine the association between yield and yield components in genotypes of sesame.

Materials and Methods

Experimental Material:

Field experiments were conducted using 25 varieties of *Sesamum indicum*. The details of the varieties along with their seed coat colour are given (Table 1) in a tabulated from.

An experiment using 25 varieties was conducted during the *Pre-kharif* season 2022 under field conditions. The experiment was carried out at Baruipur Agricultural farm, University of Calcutta. The sowings were done in first week of March, 2022 following Randomized Complete Block Design with three replications. 40cm row to row spacing and 10cm plant to plant spacing was maintained. Block area (number of rows/block) was adjusted according to the availability of seeds. Nitrogen (N), Phosphorous (K), Potassium (K) and Sulphur (S) fertilizers were applied in the fields in the form of urea, single super phosphate, muriate of potash and elemental sulphur @ 50 (N): 25 (P): 15 (K): 15 (S) Kg/Ha respectively. All of phosphorous, potassium, sulphur and half of nitrogen fertilizer were applied as basal dose just prior to first irrigation at 7 days after sowing (DAS). The rest of nitrogen was applied as foliar spray at 21 DAS. The second and third irrigations were given during flowering (30-35) and capsule filling (55-60 DAS) respectively.

Weeding was done approximately at 15 days interval. Handpicking of infected and/or diseased seedlings initially, then that of infected and/or diseased leaves and capsules were carried out all through the crop season at every experimental site. Detergent solution diluted @ 4gm/litre was also applied @ 1.5-2 litre/Ha as and when necessary to prevent the attack of caterpillars. Ten randomly selected plants from each line were observed for the morphological characters mentioned below and were harvested individually.

Record of Morphological data:

Three randomly selected plants from each variety were taken and the following parameters were studied: Plant height (cm), No of Primary branches/ Plant: Days to 50% flowering (days), Days to Maturity (days), Capsule Length (cm), Number of Capsules per Plant, Seeds per capsule,1000 Seed Weight (gm): Seed Yield/Plant (gm/plant).

TABLE 1. List of experimental material

Sl. No.	Genotype	Sl. No.	Genotype
1	EC-90	14	THILATHARA
2	SAVITRI	15	JLT-408
3	EC-103	16	RT-351
4	RAMA	17	GT-2
5	IC-59	18	IVTS-16
6	CUMS-06	19	G-17
7	CUHY-57	20	TKG22
8	CUMS-17	21	GERMPLASM 80
9	G-14	22	IVTS-12
10	CUMS-20	23	IVTS-7
11	G-30	24	PRACHI
12	CU-12	25	SHEKHAR
13	IC-64		

Results and Discussion

Character association among yield and yield components

Yield is a very complex quantitative character and is also affected by environmental fluctuation. The knowledge about yield and yield components help to achieve the desired level of improvement in yield. ANOVA for eight characters revealed that replications differed much for most of the characters. Treatments were significantly different from each other indicating high diversity.

Estimation of genetic parameters:

The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) revealed that Phenotypic coefficient of variation (PCV) was found to be greater than the genotypic coefficient of variation (GCV) for all the nine characters studied (Table..), which reflected the role of environment in the expression of the observed traits. Sumathi and Gidey et al., (2013), Iqbal et al (2016)also reported similar finding earlier. Highest coefficients of variation (phenotypic) were exhibited by seed yield/ plant (33.08 %), followed by no. of primary branches/ plant (27.4%), no. of capsules/plant (27.26%), 1000 seed weight (15.00%), plant height (12.01%), days to 50% flowering (11.71%), capsule length (10.03%), seeds/capsule (9.57%), days to maturity (5.79%).

Estimates of GCV showed a similar trend for the above mentioned traits. The phenotypic and genotypic coefficient of variation was high for number of capsules/plant, seed yield/plant. Higher genotypic coefficient of variation suggests that these characters are under the influence of genetic control. Therefore, these characters can be relied upon and simple selections can be practiced for further improvement. These results are in agreement with those of Patil and Sherif (1966) and Reddy *et al.*, (2001). Traits with high heritability estimates can be utilized for genetic improvement as they have potential for large genetic determination (Vasline *et al.* 2000). The heritability estimates were found to be high for days to 50% flowering (86.11%), days to maturity (79.05%), seed yield/plant (77.67%), capsule length (63.16%), no. of capsules/plant (61.63%), which indicated that these characters were least influenced by the environmental effects and high capacity of the characters for transmission to subsequent generation. Similar findings were reported for one or more character in sesame by Saxena and Bisen 2017. The estimates of heritability (broad sense) include both additive and non-additive gene effect and its higher estimates in broad sense indicates that the trait is least influenced by environmental effects (Shim, *et al.*, 2001).

Correlation coefficients

Correlation between plant characters and yield assume special importance in formulating a basis of selection. Genotypic and phenotypic correlation coefficients in all possible combinations among nine characters (Table-3). Highly significant positive phenotypic correlation coefficient was observed between seed yield and its four attributes namely plant

TABLE 2. Components of genetic variability in sesame

	Range	Mean	G.C.V (%)	P.C.V (%)	H(%)
Days to 50% Flowering	29-43.50	36.08	13.067	14.863	86.50
Plant Height (cm)	65.38 -156.30	92.90	22.015	22.199	92.03
No: of primary branches/Plant	1-4	2.37	54.489	55.369	88.71
No: of Capsules/Plant	60-143	63.01	16.792	17.626	93.19
Capsule Length (cm)	1.79-3	2.35	11.014	11.183	87.72
No: of Seeds/Capsule	48.77-71.76	60.05	10.98	11.649	91.09
1000 seed wt (gm)	2.77-4.35	3.15	12.143	13.442	90.85
Seed yield/Plant (gm)	8.21-17.59	11.92	13.085	14.987	89.60

height, branches per plant number of capsules/ plant and 1000 seed weight. Thus selection of any of these characters would lead to the improvement of seed yield/ plant. The correlation studies by and large support observation by Nimbalkan *et.al.* (1999) who observed the importance of plant height, number of capsules/ plant and number of seeds/capsule on seed yield/plant.

Table 3. Phenotypic Correlation Matrix

	Days to 50% flowering	Plant height	No. Of primary branches/ plant	No. Of capsules/ plant	Capsule length	No. Of / seeds capsule	1000 seed weight	**Seed yield/ Plant**
Days to 50% flowering	1.000	0.070	0.151	0.052	-0.308	-0.059	-0.197	-0.028
Plant height		1.000	-0.029	0.308	0.289	0.089	0.049	0.324
No. Of primary branches/ plant			1.000	0.534**	-0.027	0.127	-0.129	0.466**
No. Of capsules/ plant				1.000	0.020	-0.006	-0.107	0.825**
Capsule length					1.000	0.037	0.175	0.183
No. Of seeds/capsule						1.000	-0.025	0.204
1000 seed weight							1.000	0.338*
Seed yield/ Plant								1.000

*Significant at 1% Level
**Significant at 5% Level

However, a few inter- relationships were consistently significant and positive namely capsules/ plant with plant height and number of primary branches per plant, Thus selection for plant height would not only improve no. of capsules/plant and number of primary branches per plant but also will improve seed yield/plant through correlated response. Thus the correlation studies highlighted the importance of namely plant height and primary branches per plant.

Path coefficient analysis:

In order to have closer view of relationship between traits it is imperative to provide an effective means of untangling direct and indirect causes of association which would permit a critical examination of the specific forces acting to produce a given correlation. An attempt has been made in the present study to find out the direct effect of each causal factor component and its indirect effect via another factor component on seed yield/plant with the help of path coefficient analysis (Wright 1934). This method has already been proved to be very useful in plant selection and breeding depending upon one or more causal factor (Dewey and Lu, 1959). Path coefficient analysis of eight characters at phenotypic level revealed that no. of capsules/plant exhibited highest positive direct effect on seed yield/plant (Table-4), the other important contributing characters are 1000 seed weight followed by number of primary branches per plant and plant height (Kumar *et al* 2022, Kumar & Vivekanandan 2009). The indirect effects of no. of capsules/plant, number of seeds/capsule and 1000 seed weight were also positive on seed yield via several other characters. It may therefore be assumed that a sesame plant type with more number of capsules/plant having more number of seeds/ capsule and bold seed size would be ideal for obtaining higher seed yield/plant.

The present study suggested that the selection based on the characters, plant of no. of capsules/plant, number of seeds/capsule and 1000 seed weight would be effective for the development of sesame through breeding.

TABLE 4. The Path Coefficient Table

	Days to 50% flowering	Plant height	No. Of branches/ plant	No. Of plan	Capsule length	No. Of seeds/ capsule	1000 seed weight
Days to 50% flowering	**0.276**	0.068	0.239	0.111	-0.213	-0.001	-0.116
Plant height	0.092	**0.373**	0.032	0.277	0.250	0.186	0.306
No. Of primary branches/plant	-0.350	-0.035	**-0.404**	-0.275	0.213	-0.076	0.241
No. Of capsules/plant	0.341	0.627	0.575	**0.846**	0.146	0.133	-0.203
Capsule length	0.038	-0.033	0.026	-0.008	**-0.049**	-0.021	-0.029
No. Of seeds/capsule	0.001	-0.089	-0.034	-0.028	-0.076	**-0.179**	-0.198
1000 seed weight	-0.187	0.366	-0.266	-0.107	0.269	0.492	**0.446**
Genotypic correlation with Seed yield per plant	0.210	1.277	0.168	0.815	0.540	0.533	0.446

Bold values are direct effects
Residual effect = 0. 482

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Exploring Genetic Variability and Biochemical Factors Influencing Cooking and Eating Quality in Rice Cultivars

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Abstract

Rice (*Oryza sativa* L.) quality traits are crucial for consumer preference and market value, yet many breeding programs have prioritized yield over quality improvement. This study evaluated sixty rice genotypes for nine key quality traits, including physical, chemical, and cooking characteristics, to explore genetic variability and identify superior cultivars. Significant variation was observed across genotypes for all traits, revealing substantial genetic diversity. Cluster analysis grouped the genotypes into two major clusters, indicating broad genetic diversity that transcends geographical origins, suggesting breeding practices as a driving factor in shaping this variation.The study identified significant correlations between several key quality traits, including alkali spreading value, amylose content, gel consistency, and elongation ratio, with yield performance. Genotypes such as Dudheswar, IR-36, Minikit, Shatabdi, and Khitish exhibited desirable intermediate amylose content, superior elongation ratio, and improved head rice recovery, highlighting their potential for breeding programs focused on both quality and yield improvement.The results emphasize the importance of integrating quality traits into rice breeding strategies to meet consumer demands for high-quality rice varieties. These findings provide valuable insights for future breeding programs aimed at developing rice cultivars with enhanced cooking and eating qualities alongside high yield potential, contributing to both market success and food security.

Keywords : Biochemical profiling, Cooking and Eating Quality (CEQ), Genetics variability, *Oryzasativa* L.

Introduction

Rice (*Oryza sativa* L.) is one of the earliest domesticated crops and serves as a staple food for nearly half of the world's population, especially in Asia, where it provides the primary source of calories for over 3 billion people (FAO, 2022). As a major global commodity, rice is grown across diverse ecosystems, spanning Asia, Africa, and Latin America. It plays a crucial role in food security, livelihoods, and economic stability, particularly in countries like China, India, Indonesia, and Bangladesh. The significance of rice in daily diets is profound, with its cultivation providing the principal source of income for millions of households globally (Zhao *etal*., 2021).

The increasing demand for high-quality rice in both domestic and global markets has shifted the focus of rice breeding programs from merely enhancing yield to improving grain quality traits (Fitzgerald *et al*., 2020; Wang*et al*., 2021). Rice quality encompasses various attributes, including processing (milling), appearance, cooking, eating, and nutritional qualities.Among these key quality traits, cooking and eating quality (CEQ) are of particular importance, as they directly influence consumer preferences and market value. Among these, several biochemical determinants, including amylose content (AC), gelatinization temperature (GT), and gel consistency (GC) are critical for the cooking and eating qualities of rice (Champagne, 2019; Juliano, 2020).These traits are shaped not only by genetic factors but also by environmental conditions, affecting the final product's texture, flavour, and aroma, which are key factors in consumer preferences.

Genetic variability plays a crucial role in the improvement of rice cultivars for superior CEQ traits. Numerous studies have highlighted the presence of significant genetic diversity in rice populations, which can be leveraged for trait improvement (Huang *et al*., 2020). The distinctive aroma of fragrant rice varieties, such as basmati and jasmine, is primarily due to the presence of 2-acetyl-1-pyrroline, a compound synthesized through a complex biochemical pathway involving amino acids and polyamines. Advances in molecular breeding have enabled the enhancement of these aromatic traits, increasing the value of these specialty rice types in global markets (Singh *et al.*, 2021).

Biochemically, the composition of rice grain influences both its functional properties during cooking and the sensory attributes perceived during consumption. Starch, the main component of rice grains, consists of amylose and amylopectin, whose relative proportions greatly influence rice texture and eating quality (Tian *et al.*, 2020). High amylose rice tends to be firm and non-sticky after cooking, while low amylose rice is softer and stickier, which is preferred in certain culinary traditions (Fang *et al.*, 2021). Furthermore, protein and lipid content, as well as volatile compounds, contribute to flavour and aroma profiles, adding further complexity to consumer preference for rice cultivars (Ramtekey *et al.*, 2021).

This study aims to assess the genetic variability and biochemical traits among a diverse set of rice cultivars, with a particular focus on cooking and eating quality. By integrating genetic analysis with detailed biochemical profiling, the research seeks to uncover the underlying genetic and biochemical mechanisms governing CEQ traits in rice, providing insights that can aid in selecting superior parents for breeding programs, aiming to develop high-quality rice varieties tailored to consumer preferences.

Materials and methods

Plant material

Sixty rice genotypes in total (Table 1) were picked up for the current study from different KVKs and Regional Research Stations.

The experiment was conducted in three parts: physical grain quality, chemical grain quality, and cooking and eating quality parameters.

Physical quality

Head rice recovery percentage

Head rice recovery percentage was calculated by determining the weight of total milled rice and expressing it as a percentage of the weight of rough rice (Juliano, 1985):

$$\text{Head rice} = \frac{\text{Weight of total milled rice}}{\text{Weight of rough rice}} \times 100$$

Length-breadth ratio of grains (L/B ratio)

The length-breadth ratio was calculated as the ratio of the grain length to its breadth (IRRI, 2013). Based on this ratio, grains were classified as slender, medium, bold, or round (Table 2).

$$\text{Length} - \text{breadth ratio} = \frac{\text{Length of whole grain}}{\text{Breadth of whole grain}}$$

Chemical quality

Amylose content (AC)

The amylose content of rice was quantitatively determined using a standardized spectrophotometric method (Juliano, 1971). Initially, a representative sample of milled rice (1 g) was finely ground and mixed with distilled water in a volumetric flask, followed by gelatinization at 60°C for 30 minutes. Upon cooling, the solution was brought to a final volume of 100mL. Subsequently, an iodine-potassium iodide solution was added, resulting in the formation of a blue complex indicative of amylose presence. The absorbance of this complex was measured at 620 nm using a spectrophotometer. Amylose content was calculated using a standard curve derived from known amylose concentrations, with results expressed as a percentage of total starch in the sample.Rice varieties were categorized based on amylose content and their corresponding cooking characteristics (Table 3).

Gel consistency (GC)

The gel consistency of rice was determined

TABLE 1. Description of Rice germplasm under study

Sl. No.	Germplasms	Collected from	Sl. No.	Germplasms	Collected from
1	G.S.R-6 (D.R.R -42)	Maldah	**31**	Shorn	Chhatna, Bankura
2	Ajit	Maldah	**32**	Bhootmuri	Chhatna, Bankura
3	Sujala	Maldah	**33**	Annapurna	Chhatna, Bankura
4	Swarna	Maldah	**34**	Pratiksha	Chhatna, Bankura
5	Sukumar	Maldah	**35**	BB11	Chhatna, Bankura
6	MTU 7029	Maldah	**36**	Lolat	Chhatna, Bankura
7	Sahabhagi Dhan	Maldah	**37**	BB1	Chhatna, Bankura
8	Rajdeep	Maldah	**38**	IR 36	Chhatna, Bankura
9	Puspa	Maldah	**39**	Baid Shorn	Chhatna, Bankura
10	Kanak	Maldah	**40**	Super Shyamoli	Chhatna, Bankura
11	SR 26B	Canning	**41**	Khandagiri	Chhatna, Bankura
12	CSR 1	Canning	**42**	Shatabdi	Rathindra KVK
13	CSR 2	Canning	**43**	Rani Dhan	Rathindra KVK
14	Utpala	Canning	**44**	BRRI Dhan	Canning
15	Pokkali	Canning	**45**	Boby	Canning
16	CST 7-1	Canning	**46**	Sabita	Canning
17	Nona Bokra	Canning	**47**	Annada	Canning
18	Canning 7	Canning	**48**	Bidhan-2	Canning
19	Pankaj	Canning	**49**	Sumati	Canning
20	CSR 38	Canning	**50**	IRRI 147	Canning
21	Gosaba-5 (1)	Canning	**51**	WGL 20471	Canning
22	Khitish	Canning	**52**	Manisha	Canning
23	Gosaba-6	Canning	**53**	BRRI Dhan 53	Canning
24	Namita Dipti	Canning	**54**	Minikit	Canning
25	Gosaba-5 (2)	Canning	**55**	CSR 16	Canning
26	BHUTNATH	Chhatna, Bankura	**56**	Gitanjali	Canning
27	MTU 1010	Chhatna, Bankura	**57**	BRRI Dhan 57	Canning
28	Kakrisal	Chhatna, Bankura	**58**	Koushalya	Canning
29	Madhumoy	Chhatna, Bankura	**59**	Dudheswar	Canning
30	Danar Gudi	Chhatna, Bankura	**60**	Tulaipanji	Mohiniganj, North Dinajpur

Table 2. Classification of rice grains based on Length-breadth ratio

Scale	Size Shape	L/B Ratio (mm)
1	Slender	Over 3
3	Medium	2.1-3.0
5	Bold	1.1-2.0
9	Round	1.0 or less

Table 3. Categorization based on amylose content and their corresponding cooking characteristics

Grain Type	Amylose Range (%)	Type of Cooked Rice
Waxy	1-2	Moist, sticky, glossy
Non-waxy	2-9	Moist, sticky
Low Amylose Content	10-20	Sticky, soft
Intermediate Amylose	20-25	Dry, flaky, soft
High Amylose Content	25-30	Dry, flaky, hard

using a standardized procedure(Cagampang*et al.*, 1973) to assess its cooking quality. Initially, a sample of milled rice (5 g) was weighed and thoroughly rinsed with distilled water to remove excess surface starch. The rinsed rice was then soaked in 30 mL of distilled water for a specified duration (typically 30 minutes) to allow for adequate hydration. Following soaking, the rice was cooked in a boiling water bath for 30 minutes, after which it was transferred to a cooling bath to equilibrate. Once cooled, the length of the gel formed was measured using a ruler to the nearest millimeter (Table 4).

Alkali spreading value (ASV) and gelatinization temperature (GT)determination

The Alkali Spreading Value (ASV) and Gelatinization Temperature (GT) of rice were determined using standardized methodologies(Little *et al*., 1958) to assess their cooking quality and textural properties. For the ASV, a sample of milled rice (5 g) was soaked in 25 mL of 0.1 N sodium hydroxide (NaOH) solution for 30 minutes at room temperature. Following the soaking period, the extent of spreading of the rice grains was evaluated visually and classified according to a scoring system ranging from 1 (low, grains not affected) to 7 (high, grains completely dispersed). This assessment provides insights into the degree of starch gelatinization and the overall quality of the rice sample.

For the determination of Gelatinization Temperature, the same rice sample was utilized to ensure consistency in evaluation. The sample was heated in 25 mL of distilled water in a boiling water bath for 30 minutes to achieve complete gelatinization.

Table 4. Classification of gel consistency of rice grains based on gel length (mm)

Gel length (mm)	Description
27-35	Hard
36-40	Medium hard
41-60	Medium
61-100	Soft

Upon cooling, the extent of gelatinization was assessed, categorizing the temperature as high (<77°C), intermediate (77-80°C), or low (>80°C) based on the degree of swelling and texture of the rice grains. Both ASV and GT serve as crucial indicators for understanding the cooking behaviour and consumer preferences associated with different rice varieties, thereby facilitating the selection of suitable cultivars for various culinary applications (Table 5).

Cooking quality

The cooking quality of rice was assessed through the evaluation of elongation ratio, volume expansion ratio, and water uptake ratio. The elongation ratio was determined by measuring the increase in kernel length after cooking relative to its uncooked length, providing an indication of post-cooking grain expansion (Juliano, 1985). All the rice germplasms are categorized based on the elongation ratio which is scaled from 1 to 7 (Table 6). The volume expansion ratio was calculated as the ratio of the volume of cooked rice to the volume of uncooked rice, reflecting the degree of swelling during cooking (Champagne *et al*., 1998). Water uptake ratio, an important indicator of cooking quality, was measured as the weight of cooked rice relative to uncooked rice, indicating the grain's capacity to absorb water during the cooking process (Bhattacharya, 2011). These parameters are critical for understanding the textural properties and overall cooking performance of rice varieties.

TABLE 5. Categorization based on alkali spreading value and their gelatinization temperature

Score	Alkali Spreading Value	Grain Characteristics	Gelatinization Temperature
1	Low	Grains not affected	High (>77.4°C)
2	Low	Grains swollen	High (>77.4°C)
3	Low/Intermediate	Grains swollen, collar incomplete, narrow	High/Intermediate
4	Intermediate	Grainsswollen, collar complete, wider	Intermediate
5	Intermediate	Grain split or segmented, complete wider	Intermediate
6	High	Grain dispersed, merging with collar	Low
7	High	Grain completely dispersed and intermingled	Low

TABLE 6. Classification based on elongation ratio

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

Result and discussion

Physical, chemical and cooking quality traits

The cooking quality characteristics of 60 rice varieties were evaluated based on head rice recovery (HRR), length-to-breadth (L/B) ratio, amylose content (AC), gel consistency (GC), alkali spreading value (ASV), gelatinization temperature (GT), elongation ratio (ER), volume expansion ratio (VER), and water uptake ratio (WUR). The results (Table 7) demonstrate significant variability among the varieties, highlighting their potential for breeding programs aimed at enhancing cooking quality.

The analysis of physical grain quality traits revealed significant variability among the rice varieties studied. The head rice recovery percentage (HRR) ranged from a low of 49.60% in Annada to a remarkable 87.06% in Swarna, with selected checks Satabdi (59.42%), Khitish (55.94%), and Dudheswar (65.43%) showing moderate HRR values. The high HRR of Swarna indicates its superior milling efficiency, a crucial factor for commercial rice production as it directly influences profitability. In contrast, the low HRR of Annada suggests potential challenges in milling performance, emphasizing the need for enhanced processing methods or breeding strategies to maintain grain integrity and reduce breakage during milling (Tuteja*et al*., 2020). Furthermore, the length-breadth (L/B) ratio ranged from 1.95 for Canning 7 (bold) to 6.26 for Sukumar (slender), with check varieties like Satabdi (3.575) and Khitish (3.71) classified as medium slender. This preference for slender grains highlights the importance of aesthetic appeal and texture in consumer choices, especially in South Asian cuisines (Punia and Kumar, 2022).

Chemical characteristics, including amylose content (AC) and gel consistency (GC), were also evaluated. The AC ranged from 16.9% in Annapurna to 30.75% in Sabita, with check varieties Satabdi (20.64%) and Minikit (19.63%) exhibiting medium AC levels. Higher amylose content often results in firmer, less sticky rice, while medium AC is associated with softer, stickier textures preferred for certain culinary applications (Dangi*et al*., 2021). Gel consistency scores varied significantly, from 22 mm in Sabita (hard rice) to 122.50 mm in Satabdi (soft rice), aligning with local preferences in West Bengal for softer rice varieties. Varieties such as Dudheswar (112 mm) and Khitish (85 mm) also displayed soft rice characteristics, indicating their potential for palatability in traditional dishes (Mohidem*et al*., 2022). Moreover, the alkali spreading value (ASV) ranged from 1.87 for Bhuthnath to 7 for Annada, with Dudheswar (4) and Minikit (4.23) showing intermediate values, which are generally preferred for cooking.

The cooking quality characteristics further illustrate the differences among the rice varieties. The elongation ratio varied from 1.09 for BB11 to 2.65 for Sukumar, with Satabdi (1.29), Khitish (1.69), and Dudheswar (1.82) demonstrating favorable elongation ratios. High elongation ratios are indicative of a rice's ability to remain fluffy and separate during cooking, enhancing the overall dining experience (Ahmed*et al*., 2020). The volume expansion ratio (VER) ranged from 2.56 for Bhuthnath to 7.00 for IR 36, with check varieties exhibiting values of 3.42 (Satabdi), 3.62 (Khitish), and 3.99 (Minikit). Higher VER values indicate better water absorption and cooking performance, which are essential for satisfying consumer demands for soft and voluminous rice (Rahman et al., 2022). Lastly, the water uptake ratio (WUR) ranged from 2.89 for Danar Gudi to 5.23 for Sabita, with Satabdi (3.37), Khitish (5.06), and Dudheswar (4.25) exhibiting considerable water uptake. This trait is crucial for producing moist and tender rice, further influencing consumer satisfaction (Sultana*et al*., 2022).

Cluster analysis of sixty genotypes through distance matrix based on nine quality traits

The genetic diversity among sixty rice genotypes was assessed using cluster analysis based on nine quality traits, revealing two major clusters: Cluster I with 20 genotypes and Cluster II containing 40 genotypes (Table 8). Each of these clusters was further divided into two sub-clusters (A and B). This classification underscores the complexity of genetic relationships among the genotypes, indicating diverse breeding backgrounds and adaptive traits that may not

TABLE 7. Assessment of quality parameter of 60 rice genotype

Sl. No.	Variety	HRR (%)	L/B	AC (%)	GC (mm)	ASV	GT	ER	VER	WUR
1	G.S.R-6 (D.R.R -42)	61.00	4.04	20.8	56	3.56	HI	2.11	4.18	4.66
2	Ajit	69.88	3.65	24.21	85	3.51	HI	1.71	5.23	4.12
3	Sujala	70.12	5.18	23.98	84	3.21	HI	2.36	4.38	3.95
4	Swarna	87.06	2.75	20.23	47	2.66	High	1.14	4.67	3.23
5	Sukumar	71.11	6.26	23.23	87	3.25	HI	2.65	5.35	3.98
6	MTU 7029	67.61	2.57	22.48	46.2	3.00	HI	1.13	4.00	3.55
7	Sahabhagi Dhan	73.25	3.30	21.36	57	4.70	Intmd	1.65	3.68	3.98
8	Rajdeep	66.11	3.00	25	44	4.00	Intmd	1.58	4.61	4.35
9	Puspa	58.70	2.18	24.81	55	5.00	Intmd	1.11	3.94	4.21
10	Kanak	61.31	3.02	23.89	23	4.50	Intmd	1.59	4.87	4.12
11	SR 26B	65.98	2.83	22.35	48	3.65	HI	1.19	5.12	3.99
12	CSR 1	61.32	4.69	21.10	48	3.89	HI	2.10	5.49	3.74
13	CSR 2	62.21	3.85	22.15	52	4.10	Intmd	1.26	4.33	3.84
14	Utpala	64.50	3.22	22.84	51	2.96	High	1.71	3.65	3.93
15	Pokkali	67.32	3.34	23.86	65	3.65	Intmd	1.82	3.99	4.07
16	CST 7-1	59.31	3.95	23.25	61	2.45	High	1.93	3.50	3.66
17	Nona Bokra	59.85	2.87	21.65	49	3.68	HI	1.29	4.53	3.96
18	Canning 7	54.32	1.95	20.12	47	3.87	HI	1.35	3.97	4.28
19	Pankaj	59.61	3.03	27.45	69	3.16	HI	1.60	6.00	3.67
20	CSR 38	62.21	3.58	21.45	53	4.02	Intmd	1.74	4.15	4.92
21	Gosaba-5 (1)	51.75	2.39	24.36	56	2.99	High	1.11	2.98	4.77
22	Khitish	55.99	3.75	22.84	85	4.08	Intmd	1.69	5.42	5.06
23	Gosaba-6	51.25	3.81	24.96	59	3.21	HI	1.86	3.05	4.81
24	Namita Dipti	51.32	2.59	22.36	78	3.55	HI	1.19	3.68	4.06
25	Gosaba-5 (2)	52.26	3.08	24.12	57	3.03	HI	1.62	4.01	4.87
26	Bhuthnath	54.66	3.41	21.20	59	1.87	High	1.71	2.56	3.67
27	MTU 1010	65.32	4.57	21.56	79	3.05	HI	2.25	3.97	4.18
28	Kakrisal	53.26	4.64	17.36	63	2.01	High	2.29	2.61	3.65
29	Madhumoy	54.39	3.99	19.23	64.50	1.99	High	2.01	2.96	3.14
30	Danar Gudi	51.29	2.85	18.25	66.50	1.68	High	1.26	2.90	2.89
31	Shorn	53.26	2.57	19.63	67	3.01	HI	1.19	2.77	2.96
32	Bhootmuri	50.23	3.39	21.47	61	2.87	High	1.71	2.64	3.01

Sl. No.	Variety	HRR (%)	L/B	AC (%)	GC (mm)	ASV	GT	ER	VER	WUR
33	Annapurna	59.63	3.29	16.9	66	2.56	High	1.68	3.05	4.51
34	Pratiksha	62.21	3.95	23.15	71	3.31	HI	1.98	3.65	4.35
35	BB11	64.32	2.12	22.35	72	2.30	High	1.09	3.69	4.18
36	Lolat	65.37	4.49	24.55	77	2.00	High	2.07	4.44	4.67
37	BB1	63.98	2.24	23.15	73	2.36	High	1.15	3.64	4.11
38	IR 36	58.40	3.60	26.78	90.50	3.39	HI	1.76	7.00	4.71
39	Baid Shorn	51.24	3.76	19.30	64	2.89	High	1.51	2.68	3.45
40	Super Shyamoli	52.39	4.97	21.65	63	2.38	High	2.29	2.99	3.67
41	Khandagiri	49.62	3.15	26.75	61	3.11	HI	1.51	3.04	3.21
42	Shatabdi	59.42	3.71	20.64	122.5	4.00	Intmd	1.29	4.50	3.37
43	Rani Dhan	61.30	3.88	24.35	98.5	4.11	Intmd	1.69	3.96	4.42
44	BRRI Dhan 55	78.35	2.89	23.52	58	4.30	Intmd	2.2	4.10	4.31
45	Boby	69.32	4.09	23.41	47	2.37	High	2.15	3.51	4.63
46	Sabita	71.60	3.67	30.75	22	2.66	High	1.77	2.66	5.23
47	Annada	49.60	2.83	25.43	50	7.00	Low	1.71	3.76	5.02
48	Bidhan-2	67.31	2.49	23.61	49	2.43	High	1.32	3.69	4.26
49	Sumati	71.32	3.07	26.36	89	2.66	High	1.49	3.83	3.56
50	IRRI 147	76.35	4.20	21.39	86	3.74	HI	2.16	4.12	4.13
51	WGL 20471	77.69	4.63	22.41	42	2.74	High	2.29	3.95	4.16
52	Manisha	59.31	3.68	23.63	78	2.65	High	1.85	4.04	3.89
53	BRRI Dhan 53	77.12	4.26	21.31	54	4.1	Intmd	2.7	4.14	4.19
54	Minikit	86.22	2.78	19.63	54	4.23	Intmd	1.29	3.99	4.98
55	CSR 16	61.35	3.12	21.15	49	3.88	HI	1.84	4.00	4.10
56	Gitanjali	55.97	3.69	22.82	83	4.0	Intmd	1.73	3.82	5.01
57	BRRI Dhan 57	70.25	2.52	25.00	56	3.8	HI	1.2	3.51	4.12
58	Koushalya	61.11	4.78	24.21	24	4.4	Intmd	2.48	4.98	4.66
59	Dudheswar	65.43	3.61	18.45	112	4.00	Intmd	1.82	5.15	4.25
60	Tulaipanji	56.15	3.35	20.50	42	2.66	High	1.86	5.25	3.21

HRR (%): Head rice recovery percentage; **L/B:** Length-breadth ratio; **AC (%):** Amylose content (%); **GC (mm):** Gel consistency (mm); **ASV:** Alkali spreading value; **GT:** Gelatinization temperature; **ER:** Elongation ratio; **VER:** Volume expansion ratio; **WUR:** Water uptake ratio, **HI:**High/Intermediate; **Intmd:** Intermediate

TABLE 8. Grouping of 60 genotypes of rice into various clusters

Cluster	Sub-cluster	No. of genotypes	Name of genotypes
I	A	18	BB11, BB1, Pratiksha, Pankaj, Pokkali, MTU 1010, Lolat, Manisha, Ajit, Sujala,Sukumar, IRRI 147,Sumati, Khitish, Namita, Dipti, Gitanjali, IR 36, Rani Dhan
	B	02	Shatabdi, Dudheswar
II	A	17	Gosaba-5 (1),Gosaba-6, Gosaba-5(2), Bhuthnath, Annapurna, Madhumoy, DanarGudi, Shorn, Bhootmuri, Kakrisal, D.R.R -42, Puspa,CST 7-1, Super Shyamoli, Khandagiri, Annada, Baid Shorn
	B	23	Kanak, Sabita, Koushalya, MTU 7029, SR 26B, CSR 1, CSR 2, Utpala, Nona Bokra, Rajdeep, Canning 7, CSR 38, Boby, Bidhan-2, CSR 16, Tulaipanji, Swarna, Minikit, BRRI Dhan 53, BRRI Dhan 55, BRRI Dhan 57,WGL 20471, Sahabhagi Dhan

be strictly confined to geographical boundaries. Such findings align with previous studies that demonstrate a lack of direct correlation between geographical and genetic diversity in rice populations, as reported by Huang *et al.* (2021).

The random distribution of genotypes from different eco-regions within the clusters highlights the significant role of human intervention, such as selective breeding and agricultural practices, in shaping the genetic diversity of rice. Previous research has shown that breeding programs can effectively enhance specific traits, regardless of the geographical origin of the genotypes (Huang *et al*., 2021; Sundaram *et al*., 2020). This observation suggests that the variation in quality traits among the genotypes is more influenced by genetic factors rather than the environmental conditions typically associated with their regions of origin. This finding is crucial for developing high-quality rice varieties, as it emphasizes the potential of utilizing diverse genetic materials from various ecological backgrounds in breeding programs.

Furthermore, the existence of sub-clusters within the major clusters indicates the presence of distinct groups of genotypes that may possess unique combinations of desirable traits, thus offering opportunities for targeted breeding strategies. For instance, sub-cluster analysis can help identify specific genotypes that excel in key quality attributes such as amylose content, gelatinization temperature, and elongation ratio, which are vital for rice cooking quality (Champagne *et al*., 2019; Tewolde *et al*., 2021). The results from this study reinforce the importance of leveraging genetic diversity in rice breeding, which could ultimately enhance the adaptability and quality of rice in varying agro-ecological zones.

Conclusion

The evaluation of the sixty rice genotypes for nine quality traits revealed significant variability in physical, chemical, and cooking quality characteristics. The cluster analysis identified two major clusters, indicating a broad genetic diversity that is not strictly aligned with geographical origins, suggesting that breeding practices have played a pivotal role in shaping this diversity.The findings emphasized the need for high-yielding rice varieties with superior quality traits, as breeding efforts have often prioritized yield over quality. Significant correlations were found between quality traits, such as alkali spreading value, amylose

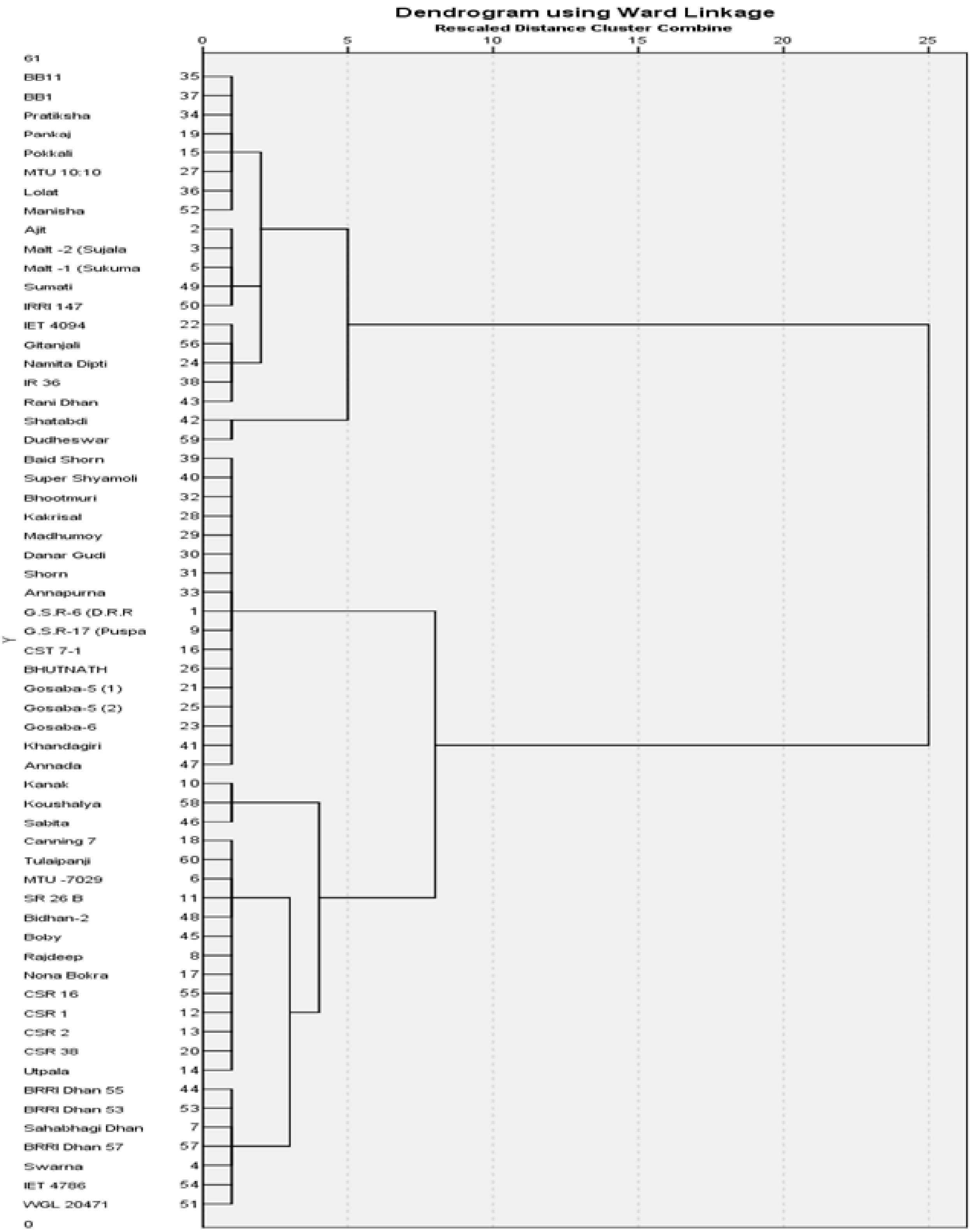

Fig. 1: Dendrogram based on the cluster analysis of sixty genotypes through distance matrix based on nine quality traits

content, gel consistency, and elongation ratio, with yield performance. Notably, genotypes like Dudheswar, IR-36, Minikit, Shatabdi, and Khitish exhibited desirable traits, including intermediate amylose content and improved head rice recovery, suggesting their potential for high market value and contribution to breeding programs aimed at enhancing both yield and quality in rice.

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Genetic Variability for Some Quantitative Characters in F_5 Families of Rice

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Abstract

Twenty-one different F_5 families derived from eight different cross-combinations were evaluated for 12 characters during warm wet (*kharif*) season (July-December) in 2018. Significant differences were observed for all the characters studied. High estimates of PCV and GCV were recorded for panicle exertion, number of filled grains, straw yield and grain yield plant^{-1}. The estimates of GCV and PCV values for panicle exertion, panicle number, secondary branches panicle^{-1}, number of filled grains, straw yield, panicle length, primary branches panicle^{-1} and grain yield showed greater difference indicating larger influence of environment on these characters. The estimates of PCV and GCV values for plant height, days to flowering and 100-grain weight showed less difference with high heritability indicating less influence of environment on these characters. High heritability in conjunction with high genetic advance for plant height, flag leaf area and panicle exertion indicated the preponderance of additive gene action. The estimates of phenotypic and genotypic correlations showed importance of primary branches and secondary branches panicle^{-1}, number of filled grains and 100-seed weight for improvement of rice yield. The results of path analyses revealed that selection of secondary branches and grain number panicle^{-1} and 100-seed weight with restricted selection on panicle number will increase grain yield in this population.

Keywords : Variability, correlations, path coefficients, quantitative characters, rice

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops belonging to the tribe Oryzae of the family Gramineae (Poaceae). The cultivated rice is diploid having 24 chromosomes (2n = 2x = 24). It ranks first among the three major cereals, followed by wheat and maize. *O. sativa* and *O. glaberrima* are believed to have evolved independently from a common ancestor *O. perennis*. In 2016, The global production of rice has been estimated to be at the 741 million tonnes, led by China and India with a combined 50% of the total. Rice provides 21% of global human per capita energy and 15% of per capita protein. In developing countries, rice accounts for 715 kcal/capita/day, 27 per cent of dietary energy supply, 20 per cent of dietary protein and 3 per cent of dietary fibre. In any plant breeding programme, availability of large genetic variability in the crop species is the first step to select better performing types among the divergent group. First attempts are made to utilize the variability present in the germplasm pool and when maximum utilization causes exhaustion of such variability, additional variability can be generated be means of hybridization. Plant breeder have to find significant correlations among yield and yield component traits, and effect of yield component traits on grain yield to predict the superior cross combinations and to select ideal plant type with increased yield. Correlation along with path analysis helps in identifying suitable selection criteria for yield improvement. So, the present study was undertaken to know the correlation among yield contributing traits and their association with yield in a population comprising advanced generation lines of some crosses.

Materials and Method

The field experiment was conducted at the Agricultural Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, which is located at sub-humid lateritic belt. The present investigation was carried out with 21 different F_5 families derived from eight different cross-combinations during warm wet (*kharif*) season (July-December) in 2018. Thirty-day old single seedling per hill was transplanted in randomized complete block design (RCBD) with three replications. Each plot consisted of 5 rows each with 20 plants with a spacing of 20 cm × 15 cm spacing. Observations were recorded on following twelve different quantitative characters *viz.* plant height, days to flowering, flag leaf area, panicle exertion, panicle length, panicle number, primary branches panicle^{-1}, secondary branches panicle^{-1}, grain number panicle^{-1}, 100-grain weight, straw yield and grain yield plant^{-1}. The data were subjected to analysis of phenotypic and genotypic coefficients of variability (Burton, 1952), heritability and genetic advance (Johnson et al., 1955a) and genotypic and phenotypic correlation (Johnson et al., 1955b) and path coefficients (Dewey and Lu, 1959).

Results and Discussion

The knowledge of genetic variability present in a population for the characters under study is of paramount importance for the success of any plant breeding programme. The estimates of genotypic and phenotypic coefficients of variance (GCV and PCV) ranged from 13.62 and 14.39 in plant height to 23.80 and 32.78 in grain yield (Table 1). Panicle exertion, number of filled grains, straw yield and grain yield plant^{-1} showed high estimates of PCV and GCV. Similar results have been reported for grain number and grain yield (Krisna *et al*., 2014). Traits like flag leaf area, panicle number, secondary branches panicle^{-1} showed high estimates of PCV and moderate estimates of GCV. Moderate estimates of PCV and GCV were found in plant height and 100-grain weight. Similar results have been reported for 100-grain weight (Sameera *et al*., 2016; Khare *et al*., 2015; Longkho *et al*., 2020). Low estimates of PCV and GCV were found for days to flowering, panicle length and primary branches panicle^{-1}. Similar results have been reported for panicle length (Sameera *et al*., 2016; Dudhane and Kole, 2017 and Gayotande *et al*., 2017). The estimates of GCV and PCV values for panicle exertion, panicle number, secondary branches panicle^{-1}, number of filled grains, straw yield, panicle length, primary branches panicle^{-1} and grain yield showed greater difference which indicated the greater role of environmental factors influencing these characters. The estimates of PCV and GCV values for plant height, days toflowering and 100-grain weight showed lower difference which indicated less sensitivity of these characters towards the fluctuating environments.

The estimate of heritability has a predictive role in expressing the reliability of phenotypic value. The estimates of heritability in broad sense (Table 1) were high for plant height (89.6%), days to 50% flowering (87.8%) and 100-grain weight (75.1%) which revealed that these characters are less influenced by environment and there could be greater correspondence between phenotypic and breeding values. Similar results have been reported for plant height (Kishore *et al*., 2018 and Mamata *et al.,* 2018); days to 50% flowering (Kahani and Hittalmani, 2015 and Mamata *et al.,* 2018); 100-grain weight (Govintharaj *et al.,* 2016; Babu *et al*., 2017 and Mamata *et al.,* 2018). The estimates of heritability were moderate for flag leaf area, panicle exertion, panicle length, number of primary branches, secondary branches panicle^{-1}, number of filled grains and grain yield plant^{-1}. Similar results have been reported for flag leaf area (Kahani and Hittalmani, 2015); panicle length (Hasib and Kole, 2008); number of primary branches and secondary branches (Dudhane and Kole, 2017); number of filled grains (Hasib *et al*., 2000 and Mamata *et al.* 2018) and grain yield plant^{-1} (Hasib and Kole, 2008). Panicle number and straw yield showed low heritability. Similar results have been reported for panicle number (Krishna *et al*., 2014).

The genetic advance as per cent of mean (GAM) is a useful indicator of the progress that could be expected as a result of exercising selection on the pertinent population. Genetic advance as a per cent of mean (Table 1) was high for panicle exertion and moderate for plant height, flag leaf area, secondary branches panicle^{-1}, number of filled grains, straw yield and grain yield plant^{-1}, and low for days to flowering, panicle length, panicle number, primary branches panicle^{-1} and 100-grain weight. Moderate GAM was reported earlier for plant height (Kahani and Hittalmani,

Table 1. Phenotype and Genotype coefficients of variability, heritability and genetic advance for twelve quantitative characters in F_5 families of rice

Characters	Grand mean	Range		Coefficient of variation (%)		Heritability(%)	Genetic advance	Genetic advance as percent of mean
		Min	Max	GCV	PCV			
Plant height(cm)	**130.69**	**96.73**	**156.54**	**13.62**	**14.39**	**89.60**	**34.71**	**26.56**
Days to flowering	**121.46**	**111**	**128.00**	**3.62**	**3.96**	**87.80**	**8.48**	**6.99**
Flag leaf area (cm^2)	**27.01**	**20.32**	**39.09**	**18.45**	**22.50**	**67.30**	**8.42**	**31.18**
Panicle excertion(cm)	**3.19**	**1.03**	**7.65**	**49.46**	**60.77**	**66.30**	**2.65**	**83.08**
Panicle length(cm)	**23.33**	**19.47**	**26.39**	**7.74**	**9.61**	**64.90**	**3.00**	**12.85**
Panicle number	**9.29**	**5.33**	**11.00**	**13.71**	**20.78**	**43.50**	**1.73**	**18.63**
Number of Primary branches	**10.94**	**9.68**	**13.55**	**7.08**	**9.11**	**60.40**	**1.24**	**11.34**
Number of Secondary branches	**24.12**	**14.95**	**35.75**	**18.88**	**24.90**	**57.50**	**7.11**	**29.49**
Grain number $panicle^{-1}$	**108.78**	**74.45**	**165.45**	**20.53**	**27.75**	**54.70**	**34.05**	**31.31**
Test weight(g)	**1.92**	**1.44**	**2.41**	**11.78**	**13.59**	**75.10**	**0.40**	**20.89**
Straw yield(g)	**42.57**	**25.93**	**67.05**	**20.67**	**31.30**	**43.20**	**11.85**	**27.84**
Grain yield per $plant^{-1}$	**16.84**	**10.95**	**29.19**	**23.80**	**32.78**	**52.70**	**6.00**	**35.63**

2016 and Mamata *et al.,* 2018), flag leaf area (Kahani and Hittalmani, 2016), secondary branches panicle^{-1} (Kumar and Senapati, 2013 and Kahani and Hittalmanni, 2016), number of filled grains (Hasib and Kole, 2000 and Mamata *et al,* 2018) and grain yield (Kahani and Hitalmani, 2016). Low estimates of GAM were observed for panicle length (Dudhane and Kole, 2017 and Mamata *et al.,* 2018); panicle number and primary branches panicle^{-1} (Dudhane and Kole, 2017) and 100-grain weight (Babu *et al.,* 2017 and Mamata *et al.*, 2018). Heritability in conjunction with genetic advance gives an indication of the nature of gene action. The estimates of the above two parameters for plant height, flag leaf area and panicle exertion indicate the preponderance of additive gene action. Therefore, these characters will respond to selection. Similar results have been reported earlier (Hasib *et al.*, 2002).

Yield is a complex trait and is the ultimate product of a number of contributing traits. Direct selection of yield shows low effectiveness. The degree of correlation among the characters is important. Therefore, association among characters was undertaken to determine the direction of selection and the number of characters to be considered in improving the yield. The estimates of phenotypic and genotypic correlations (Table 2) showed that primary branches panicle^{-1}, secondary branches panicle^{-1}, number of filled grains and test weight with grain yield at genotypic level are positive and highly significant. A strong correlation of grain yield with these traits indicates that the improvement in grain yield would be possible through selection of these traits. Similar results have been reported for primary branches panicle^{-1} and secondary branches panicle^{-1} (Kole and Hasib, 2003), grain number (Patel *et al.,* 2008 and Nandeswar *et al.*, 2010) and 100-grain weight (Hasib and Kole, 2004 and Dudhane and Kole, 2017). Plant height exhibited highly positive significant correlation with flag leaf area, panicle length, secondary branches panicle^{-1} at both genotypic and phenotypic levels and positive non-significant correlation with days to flowering and panicle exertion. Flag leaf area showed positive significant correlation with primary and secondary branches panicle^{-1}, grain number panicle^{-1} at both genotypic and phenotypic levels and with straw yield at genotypic level. Correlations of panicle length with primary branches panicle^{-1}, secondary branches panicle^{-1} and straw yield were highly positive and significant at genotypic level and positive non-significant with number of filled grains. Panicle number exhibited highly negative significant association with secondary branches panicle^{-1} at genotypic level. Primary branches panicle^{-1} showed highly positive significant correlation with secondary branches and grain number panicle^{-1} at both genotypic and phenotypic level. Association between secondary branches panicle^{-1} and grain number was positive and highly significant. Grain number showed positive and highly significant correlation with 100-grain weight both at genotypic and phenotypic level and 100-grain weight showed highly positive significant correlation with straw yield at genotypic level. Plant height had negative non-significant correlation with panicle number (Hasib and Kole*,* 2004 and Kishore, 2018) and positive significant correlation with number of filled grains (Patel *et al.,* 2018). Panicle number was negatively correlated with grain yield. Primary branch panicle^{-1} had positive significant correlation with grain number (Rai *et al.*, 2013). Grain number had positive significant correlation with 100-grain weight (Patel *et al.,* 2018). The genotypic correlation coefficients were higher than phenotypic correlation coefficient in majority cases. This indicated a strong inherent association between the characters studied and suppressive effect of the environment modified the phenotypic expression of these traits by reducing phenotypic correlation values. However, the correlation study revealed that number of primary branches panicle^{-1}, secondary branches panicle^{-1}, number of filled grains and 100-grain weight were the most important characters to be considered in the selection for improvement of rice yield in the population under investigation

The results pertaining to genotypic path coefficient analysis revealed that (Table 3) secondary branches panicle^{-1} registered the highest positive direct effect, followed by straw yield, 100-grain weight, panicle exertion, number of filled grains, panicle length and primary branches panicle^{-1}. Secondary branches panicle^{-1} showed positive direct effect and positive indirect effects through all the characters except plant

Table 2. Genotypic(G) and Phenotypic(P) correlation of twelve quantitative characters in F_5 families of rice

Characters		Days to 50% flowering	Flag area (cm^2) leaf	Panicle exertion(cm)	Panicle length(cm)	Panicle number	Primary branches	Secondary branches Panicle^{-1}	Grain Panicle^{-1}	100-grain panicle^{-1}	Straw yield(g) Weight(g)	Grain yield(g)
Plant height(cm)	G	**0.10**	**0.67****	**0.32**	**0.64****	**-0.52***	**0.64****	**0.76****	**0.68****	**0.30**	**0.54***	**0.33**
	P	**0.11**	**0.57****	**0.30**	**0.57****	**-0.37**	**0.50***	**0.59****	**0.49***	**0.26**	**0.37**	**0.22**
Days to flowering	G		**0.18**	**-0.02**	**0.17**	**-0.05**	**0.34**	**0.10**	**-0.35**	**0.09**	**0.58****	**-0.07**
	P		**0.22**	**0.01**	**0.21**	**-0.008**	**0.24**	**0.08**	**0.07**	**0.11**	**0.28**	**-0.005**
Flag leaf area (cm^2)	G			**0.21**	**0.36**	**-0.73****	**0.50***	**0.76****	**0.77****	**0.31**	**0.85****	**0.35**
	P			**0.15**	**0.37**	**-0.52***	**0.43***	**0.48***	**0.54***	**0.28**	**0.28**	**0.18**
Panicle exertion(cm)	G				**-0.39**	**-0.33**	**0.01**	**0.18**	**0.51***	**0.41**	**-0.008**	**0.37**
	P				**-0.24**	**-0.20**	**0.03**	**0.15**	**0.41**	**0.28**	**0.08**	**0.26**
Panicle length(cm)	G					**-0.09**	**0.56****	**0.55****	**0.12**	**-0.06**	**0.66****	**0.14**
	P					**-0.11**	**0.37**	**0.35**	**0.13**	**0.02**	**0.30**	**0.11**
Panicle number	G						**-0.24**	**-0.67****	**-0.60****	**0.10**	**-0.11**	**-0.07**
	P						**-0.25**	**-0.39**	**-0.35**	**0.13**	**0.09**	**0.29**
Primary branches panicle^{-1}	G							**0.80****	**0.66****	**0.42**	**0.68****	**0.61****
	P							**0.53***	**0.45***	**0.26**	**0.20**	**0.36**
Secondary branches panicle^{-1}	G								**0.85****	**0.29**	**0.52***	**0.58****
	P								**0.62****	**0.18**	**0.28**	**0.35**
Grain number panicle^{-1}	G									**0.56****	**0.41**	**0.65****
	P									**0.22**	**0.14**	**0.38**
Test weight(g)	G										**0.65****	**0.76****
	P										**0.32**	**0.57****
Straw yield(g)	G											**0.28**
	P											**0.20**

Table 3. Genotypic path coefficient analysis eleven characters on grain yield in F_5 families of rice

Character	Plant height	DaysTo flowering	Flag Leaf area	Panicle exertion	Panicle length	Panicle Plant^{-1}	Primary panicle^{-1} branches	Secondary Branches Panicle^{-1}	Grain Panicle^{-1}	Test weight	Straw yield	Correlation With grainyield
Plant height	**-0.584**	-0.033	-0.442	0.116	0.111	0.022	0.072	0.599	0.139	0.109	0.228	0.337
Days to flowering	-0.063	**-0.305**	-0.121	-0.008	0.030	0.002	0.038	0.080	-0.007	0.036	0.246	-0.071
Flag leaf area	-0.397	-0.057	**-0.650**	0.079	0.064	0.031	0.056	0.599	0.158	0.113	0.360	0.355
Panicle exertion	-0.187	0.006	-0.142	**0.360**	-0.069	0.014	0.002	0.141	0.104	0.151	-0.003	0.377
Panicle length	-0.375	-0.053	-0.239	-0.143	**0.174**	0.004	0.063	0.434	0.026	-0.024	0.280	0.147
Panicle Plant^{-1}	0.305	0.105	0.478	-0.120	-0.016	**-0.042**	-0.027	-0.529	-0.123	0.040	-0.050	-0.070
Primarybranchespanicle^{-1}	-0.377	-0.105	-0.328	0.006	0.099	0.010	**0.111**	0.627	0.135	0.154	0.286	0.618**
SecondarybranchesPanicle^{-1}	-0.448	-0.031	-0.499	0.065	0.097	0.029	0.089	**0.781**	0.173	0.108	0.219	0.582**
Grain Panicle^{-1}	-0.401	0.011	-0.506	0.185	0.022	0.026	0.074	0.667	**0.203**	0.205	0.172	0.657**
Test weight	-0.175	-0.030	-0.202	0.151	-0.011	-0.005	0.047	0.232	0.115	**0.362**	0.273	0.756**
Straw yield	-0.317	-0.179	-0.559	-0.003	0.116	0.005	0.075	0.409	0.083	0.236	**0.419**	0.286

Bold figures indicate direct effect

Residual effect=0.1912; *, ** Significant at p=0.05 and p=0.01, respectively;

height, days to 50% flowering and flag leaf area resulting positive highly significant correlation with grain yield. Straw yield exerted positive direct effect and positive indirect effects through panicle length, panicle number, number of primary branches, number of secondary branches, number of filled grains, 100-grain weight which was counterbalanced by negative indirect effects through plant height, days to flowering, flag leaf area and panicle exertion resulting positive non-significant correlation with grain yield. positive direct effect of 100-grain weight and its positive indirect effects via panicle exertion, number of primary branches, number of secondary branches, number of filled grains and straw yield resulted positive and highly significant correlation with grain yield. Panicle exertion showed positive direct effect and indirect positive effects through days to flowering, panicle number, number of primary branches, number of secondary branches, grain number and 100-grain weight which was reduced by negative indirect effect via plant height, flag leaf area and panicle length resulting positive but non-significant correlation with grain yield. Number of primary branches registered positive direct effect and positive indirect effects through all the traits except plant height, days to 50% flowering and flag leaf area resulting positive highly significant correlation with grain yield. Number of filled grains had positive direct effect and indirect positive effects via most of the component characters which resulted positive and highly significant correlation with grain yield. Panicle length showed positive direct effect and positive indirect effects via number of panicles, number of primary branches, number of secondary branches, grain number and 100-grain weight which was counterbalanced by negative indirect effects via some traits resulting positive non-significant correlation with grain yield. Plant height, days to flowering, flag leaf area and panicle number showed negative direct effect on grain yield. Similar results have been reported earlier (Hasib and Kole, 2004 and Nath and Kole, 2021).

The low residual effect (0.19) for the genotypic path analysis indicated that the 81% variability in grain yield was contributed by the eleven characters. Values of path coefficients are less than one indicating that the problem due to multiple collinearity is minimal (Gravois and McNew, 1982).

The results of path analyses reveal that selection of secondary branches and grain number panicle^{-1} and 100-seed weight with restricted selection on panicle number will increase grain yield in this population.

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Problems and Prospects of Oilseeds Production in India with Special Reference to West Bengal

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Abstract

India is the fourth largest producer of oilseeds accounting for about 20% of the global area and 10% of the global production. Though the country has made a significant paradigm in the total oil seeds production to the extent of about 30 million tonnes in 2022-23, The country is not able to peace up with the increasing demand of oilseed brought about by the growing population growth. In the state of West Bengal oilseed scenario is not good. Oilseeds are grown approximately over 0.75 million hectors, producing about 0.82 million tonnes of production which can hardly meets 42% of requirement. The country is still importing around half of its domestic requirements of edible oils from various oil producing countries in the world. Nonconventional oilseed crops like Sunflower, Soybean can also play important role in meeting vegetable oil requirement. The article analyses the current scenario of oilseed production and their problems associated with strategies that might take the country for enhancing oilseed production for its sufficiency.

Introduction

In India annual oilseeds are cultivated over 2.67 million hectares of land producing about 31 million tonnes annually. Majority of oil seeds accounting 70% are cultivated under rainfed ecosystem. Accounting about 20% of global area with around 10% of global production, these field crops hold the second most important determinant of Indian agricultural economy only next to cereals. India being a country rich in diverse agro-ecological conditions, it has optimal conditions for the production of all nine-annual oilseed. The annual production of oilseed is increasing continuously in the country and showed a positive growth during the period 2020 to 2023 compare to the 2010-2020 especially as the increased production has come from the increased in area and the highest rater of productivity by implying the technology fed growth. Galloping population with higher income is likely to further increase the domestic consumption of edible oils. The country has to increase area under oilseeds and to produce higher oilseed production to meet the requirement.

Import and export of oilseeds

India is heavily dependent on imports to meet edible oil requirements. So, the country has to import edible oil to the extent of 15% in the world. The highest amount of about 60% palm oil followed by 25% of soybean oil and 12% of sunflower oil are imported annually. Presently India has to import about 17 million tonnes of oilseed. India was never a good exporter of edible oils. India's export basket comprised of premium oils with higher value realization from refined coconut, groundnut and sesame oils, easter oil and groundnut oil contribute the larger share of imports.

Problems for low production

About 90 percent of the oilseed cultivation in India is under uncertain and abnormal weather conditions. Irregular rains and alternate irrigation sources at maturity largely affect the final yield. In West Bengal over 70 percent rice is grown in wet season with receipt of south-west monsoon. Under such agro-ecosystem majority of rice area approximately 80 percent planted with traditional long duration season bound *aman* rice. Such rices are planted in June- July and harvested by November – December when most of the oil seed crops miss the optimal time of sowing. Hence most of the oilseed crops are grown on up and medium lands. Nearly 16% and 42% lands are upland and medium land and there is competition for cereals, pulses and oilseed crops. Most of the poor and marginal lands are relegated to poor and marginal lands. Further many of the oilseed crops have been cultivated under marginal and sub marginal conditions with poon management. The cumulative effect off all this has resulted in not only low productivity but also instability.

Constraints in production

Though oilseeds are energy reach crops requiring higher inputs with better management practices. Oilseed crops are generally fall under rainfed conditions and grown in energy starved crops with low inputs and poor management conditions. Most of the cultivars and hybrids are drought susceptible and the high yielding variety are also not suitable. They are generally long duration and also do not have higher level of oil content. The crops are generally grown by small and marginal farmers under unirrigated areas with poor management practices. Thess crops are highly affected by pests and disease like powdery mildew cause great damage to important oilseed crops. Lack of mechanization for sowing and harvesting of crop as these crops has high scattering property at the time of harvesting. There is also lack of suitable post-harvest technology to prevent post-harvest losses.

Approaches for increasing production and productivity

The oilseed cultivation in India has received very little attention. The experimental evidences have shown that these crops could be grown in nontraditional areas. Rapeseed- mustard is grown mostly in north India above 20^0 N latitude. It can be grown in peninsular India below 20^0N latitude. The crop can also be grown in eastern India (Rao, 1988). There are enormous possibility for expanding *Kharif* groundnut as a pure crop in unbounded high lands, uplands rice area of many eastern states. Expansion of area under *rabi* in summer groundnut and through intercropping is also possible. Similar opportunities in case of other oilseed crops should also be explored to push up oilseed production in the country.

Sequence Cropping:

Tremendous success achieved in introducing paddy-wheat, cotton-wheat and arhar-wheat based double cropping system in Punjab, Haryana, Western Uttar Pradesh and so on, where it was possible earlier to grow only one crop a year, has given a positive impetus to advance this concept to more crop under irrigated as well as rainfed conditions. There are also possibilities of crop combination such as greengram-safflower-sorghum-sunflower, groundnut-safflower, seasame-safflower and so on. Additional output and complementary yield of sequential cropping are the two main advantage occurring to rainfed farming community.

Relay cropping

The underlying principle is to take advantage of residual moisture to take two crops in a year where traditionally only one crop is grown by adopting an overlapped cropping system. The system essentially consists of sowing by broadcast linseed, khesari (lathyrus) in the standing crop of paddy when the latter is in dough stage, perhaps around 20 days before the harvest of paddy. After that the germinated seedlings sown in rice would pickup growth and complete their cycle. Similar possibilities exist for relaying soybean, sunflower, soybean-sunflower in parts of India.

Intercropping

Most of the oilseed crps are grown in intercropping system in India. Intercropping has several advantages. The principal advantage is that the system distributes risk and ensures against crop failure. Suitable crop combinations and their appropriate management practices have been worked out for oilseed crops. The system of intercropping consists of additive series and replacements series. Some good examples of intercropping commonly practiced are cotton +sunflower, cotton+ soybean, potato+ mustard, potato+ linseed, sugarcane+ mustard, chickpea + mustard and system and resource-based agronomy for various oilseed intercropping system needs to be developed.

Crop replacement

Traditionally low yielding crops under different situations could be replaced by more remunerative crops like oilseeds. The following replacement have been suggested through extensive research efforts. West Bengal is important state where olitorious jute is grown extensively on upland and medium uplands. Jute being unstable crop as yield vary considerable year to year and the price of raw jute in most variable. Hence groundnut has been taken as a most important potential crop which can replace upland jute. Noe groundnut has proved to be a remunerative crop replacing jute.

Strategies

The strategies may be categorized under below noted situations as follows.

i. Increasing seed producing and distribution of newly released varieties

ii. Low cast technologies with high impact on productivity resulting in higher income.

iii. Strategies with emphasis on quality improvement and value addition leveraging technologies with a bearing on the employment through skill entrepreneurship development.

Conclusion

New approaches such as scientific management and special attention with new source such as corn and rice bran may be exploited. Use of latest genetic tools in oilseed improvement programmes and chemistry in oil extortion process may give tremendous impacts to sustainable production of oilseed crop.

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Ralstonia Solanacearum: A Ubiquitous Hidden Soil Borne Phytopathogen

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Abstract

Bacterial wilt causing pathogen, *Ralstonia solanacearum* is gram negative, aerobic, motile, non-spore forming, rod shaped bacteria under the class β-proteobacteria. Brazil is considered as the centre of origin of *Ralstonia solanacearum.* It is classified based on phylogenetic analysis of 16-23S ITS and egl gene sequencing into 4 phylotypes and 23 sequevars. The infected plant shows vascular browning, foliage epinasty, wilting and finally, death of the plant. For avoiding yield loss, we need to go for prophylactic measures. This is achieved by real time detection method of bacterial wilt pathogen in field. *Ralstonia solanacearum* is a complex pathogen, due to that no one method alone cannot be used for managing the pathogen. By integrated disease management approaches could be enhanced the efficiency up to 100%.

Keywords: Biotypes, Management, *Ralstonia solanacearum*, Race, Symptoms

Introduction

The world population is enormously growing day by day with limited land for cultivation. The increasing population should be fed by same land area. The food production should be increased by 70% to meet the demand of 10 billion people in 2050 (Islam *et al*., 2019; Danquah *et al*., 2021). Crop failure and Yield loss are due to the biotic and abiotic stresses caused by global warming and climate change (Pandey *et al*., 2017). Nearly 36% of the produce is affected by biotic factors including plant diseases, insect pests and weeds. In this plant diseases itself causes 14% yield loss (Agrios, 2005). The yield loss should be minimized to increase the production. Bacterial pathogen are very important in causing yield losses due to their capability to affect the biology of the crop plants (Kunkel and Harper, 2018; Bonaterra *et al*., 2022). The top ten destructive bacterial pathogens are given based on their scientific and economic importance, these are *Pseudomonas syringae* pathovars causes speck, fleck, spot, blight and canker diseases. *Ralstonia solanacearum* causes bacterial wilt, *Agrobacterium tumefaciens* causes crown gall, *Xanthomonas oryzae pv. oryzae* causes bacterial leaf blight, *X. campestris* pathovars causes black rot, *X. axonopodis* pathovars causes bacterial canker, *Erwinia amylovora* causes fire blight, *Xylella fastidiosa* causes pierce's disease, *Dickeya sp.* (former *Erwinia*) (*dadantanii* and *solani*) causes soft rot and *Pectobacterium* (former Erwinia) causes soft rot diseases respectively (Mansfied *et al*., 2012). *Ralstonia solanacearum*, bacterial wilt causing pathogen, which was ranked as the second most destructive bacterial pathogen (Mansfield *et al*., 2012; Paudel *et al*., 2020; Wang *et al*., 2023b). *Ralstonia solanacearum* species complex has spread all over the world and also it seems to be quarantine pest in many countries to prevent its further spread (EPPO, 2021). *Ralstonia solanacearum* race 3 biovar 2 was considered to be bioterrorism weapon in 2002 (Anon, 2005). It has ability to rapidly adapt to environment conditions and its high variability made them to distribute all over the world (Genin, 2010; Genin and Denny, 2012). Lower yields per unit area can be ascribed its exposure to various biotic stresses. Among the biotic stresses, ralstonia wilt is economically important causing 20-100% yield loss because of their damaging behavior and limitied control tactics (Jiang *et al*., 2017; Wang *et al*., 2023a, 2023b). However, detailed information is lacking of this disease. Keeping in view, the review was emphasized.

The Pathogen

Ralstonia solanacearum is gram negative, aerobic, motile having a tuft of flagella at one pole (*i.e.,* cephalotrichous), non-spore forming, rod shaped bacteria under the class β-proteobacteria (Yabuuchi *et al*., 1995). It is a universal pathogen having a wide host range of over 250 plant species from 54 families (Elphinstone, 2005). It has diverse species complex composed of four phylotypes (I-IV), it according to their evolution, host range, geographic origin and pathogenic behaviours (Fegan and Prior, 2005; Álvarez *et al.*, 2007; Prior, 2005). It is a soil borne bacteria (Singh *et al*., 2015) which causes vascular wilt by penetrate through wound or root tips (Bindal and Srivastava, 2019). As this is a soilborne pathogen, its survival and primary infection in soil. It can survive without host for several years by latent infection with native weeds (Lebeau *et al*., 2011; Wang *et al*., 2019). It can survive in different environments having temperature range between 10-41°C (Muthoni *et al.*, 2012). The secondary spread is through contaminated water, infested seeds and contaminated farm implements (Singh *et al*., 2015). Due to its variability and wide host range, it causes brown rot of potato, moko wilt of banana and bacterial wilt in large number of species including tomato, chilli, brinjal, mulberry and other ornamental plants etc. (Bindal and Srivastava, 2019). In result due to Bacterial wilt, it shows a significant (Aslam *et al*., 2017) yield loss more than 1 billion USD annually in the global level (Yuliar *et al*., 2015).

Origin and distribution across world

Brazil is considered as the centre of origin of *Ralstonia solanacearum* (phylotype III) and *Ralsonia pseudosolanacearum* (phylotype I) (Wicker *et al*., 2012; Santiago *et al*., 2017). The bacterial wilt disease was found in tobacco plants for the first time in 1920 (Parseval, 1922). In India, *Ralstonia solanacearum* race 1 biovar 3 was distributed almost everywhere in coastal and hilly and foot hill area includes Goa, Karnataka, Kerala, Maharastra, Orissa, Jharkhand, West Bengal and state of North eastern hills, Himachal Pradesh, Jammu and Kashmir and Uttarkhand (Devi and Menon, 1980).

Race and Phylotype

Ralstonia solanacearum is classified into 5 races (Buddenhagen *et al*., 1962) based on their host range and climatic conditions as shown in (Table 1). Race 1 strains were found in humid areas of the world. It needs an optimum temperature of 35°C or more and it mainly affect solanaceous crops like tomato, chilli, brinjal and tobacco. Race 2 strains were mainly found in hot places of South America and also it mainly affect banana and *Heliconia* spp. Race 3 strains were found at higher altitudes of tropics, subtropics and moderate areas and its need less optimum temperature of 27°C. It affects potato and some solanaceous weeds. Race 4 strains mainly affects ginger (*Zingiber officinale*). Race 5 strains affects mulberry plants (*Morus* spp.). *Ralstonia solanacearum* was divided into 5 biovars of based on the oxidation of sugar alcohols and utilization of sugars (Mbugua *et al*., 2020). *Ralstonia solanacearum* is classified based on phylogenetic analysis of 16-23S ITS and egl gene sequencing into 4 phylotypes and 23 sequevars (Fegan and Prior, 2005; Prior and Fegan, 2005). Earlier researchers proposed to divide the *Ralstonia solanacearum* into three species *viz*., *Ralstonia sequirae* (all phylotype I and III), *R. solanacearum* (all phylotype II) and *Ralstonia haywardii* (all phylotype IV, *Ralstonia celebensis* and *Ralstonia syzygii*) was reported (Genin and Denny, 2012; Remenant *et al*., 2011). *R.solanacearum* is recently characterized into 57 sequevars (Ghorai *et al.,* 2022; Santiago *et al.,* 2017).

Symptoms and Diagnosis

Warmest time of the day, the youngest leaves became flaccid in appearance (Vanitha *et al.,* 2009). Favourable environmental conditions make the whole plant wilt immediately. The pathogen enters the host through wound in roots and stems (Mansfield *et al*., 2012). The infected plant show withering caused by

TABLE 1. Host range and distribution of *R. solanacearum* based on races

Race	Host Range	Distribution	Biovar	Phylotype	References
1	Tobacco, tomato, eggplant, groundnut, potato, pepper, ginger, olive, strawberry, geranium, eucalyptus and many weeds. (wide host range)	Asia, Australia, America	3,4,1	I, III	Hayward, 1994; Genin and Boucher, 2002.
2	Triploid banana, *Heliconia sp.*	Caribbean, Brazil, Philippines	1	II, IV	Hayward, 1994.
3	Potato, tomato, some other Solanaceae, Geranium; *Pelargonium spp*., herbaceous weeds	Worldwide except United States and Canada	2	II	Elphinstone, 2005.
4	Ginger, small cardamom	Australia, China, Hawaii, India, Japan, Mauritius	3,4	I	Kumar *et al*., 2012.
5	Mulberry (*Morus* spp.)	China	5	I	Denny and Hayward, 2001; Denny, 2006

blocking of xylem vessels due to extracellular polymeric substances (EPS) and bacterial cells stop the transportation of water and minerals (Arwiyanto, 2014). The infected plant shows vascular browning along with oozing, foliage drooping, wilting. (Buddenhagen and Kelman, 1964).

The symptoms of moko disease infected banana young plants exhibited rapid wilting and also breaking of petiole at sharp angles followed by death of the plants. Older plants show discoloration and drooping of the inner leaves followed by outer leaves. The entire plant will wilt and dies. In fruiting stages, the peduncles are infected showing scars of the fallen male flowers due to infection followed by blackening of terminal bud. In fruits, it shows arrested fruit growth, premature ripening or spliting and internal fruit discoloration and finally rot. The infected pseudostems are cut open, it shows yellowish brown or black discoloration of vascular bundles (Buddenhagen, 1960). The symptoms of bacterial wilt of ginger are green wilt which is characterized by rolling and curling of leaves followed by yellowing and necrosis. The plants show stunting, decline and death. The rhizome show rotten and discoloured. The vascular bundles show discolouration (Trujillo, 1964). The affected plant show browning of vascular bundles and if the stem is cut at the base and placed in glass containing clean water, then the white bacterial oozes are seen which is used as diagnosis for bacterial wilt (Kumar *et al*., 2017). The favourable conditions are high temperature (30-35°C) and heavy soil with high moisture content (Mondal, 2011).

Estimation of yield losses in various crops

In tomato, the yield loss is due to bacterial wilt ranged from 10 to 90% (Aslam *et al.,* 2017). In potato, the yield loss ranged from 33-90%. In chilli, the yield loss ranged from 20-100% (Shekhawat *et al*., 2000). In brinjal, the yield loss ranged from 25-100% (Singh *et al*., 2010). In banana, the yield loss ranged from 80 to 100%. In ginger, the yield loss ranged up to 47.4% (Jibat and Alo, 2022). In tobacco, the yield loss ranged from 50-60% (Jiang *et al.,* 2017).

Detection of *R. solanacearum*

For reducing the yield loss, need to go for prophylatic measures. This is achieved by real time detection method of bacterial wilt pathogen in field. There are lot of techniques are used to find out the race and biovars. They are bacteriophage recognisation methods, phospholipids fattyacid analysis, serodiagnosis, PCR (Polymerase chain reaction) based diagnosis, LAMP (Loop-mediated isothermal amplification) based diagnosis, FISH (Fluorescence in situ hybridization) based diagnosis (Singh, 2017). In Multiplex-PCR, we can detect *R. solanacearum* and *Clavibacter michiganensis* subsp. *sepedonicus* in potato peel (Sebastien *et al*., 2014).

Management Practices

The second international bacterial wilt symposium was held in Guadaloupe in 1997, from that more than 450 studies had been published on *Ralstonia solanacearum* (Elphinstone, 2005). These studies showed that breeding and selection for resistance mainly concerned up to 24%, while the remaining are diversity, distribution and host range of pathogen as 22%, disease management and control as 18%, pathogenicity and host-plant pathogen interaction as 17%, biological control as 10%, detection and diagnosis of pathogen as 4% and epidemiology and ecology as 3%. Yuliar *et al.* (2015) reported that based on their reference searches from book and journals shows 54% of the searches are related to biological control, 21% as cultural practices, 8% as chemical methods, 6% as physical methods and 11% as integrated pest management. *Ralstonia solanacearum* has the ability to grow endobiotically, survive in deep soil layers, travel through water and its relation with weeds makes it difficult to control this pathogen (Wang and Lin., 2005).

Chemicals are expensive and also repeated application should be done for economically valuable crops only. *Ralstonia solanacearum* is controlled by pesticide such as fumigants (metam sodium, 1,3-dichloropropene, and chloropicrin), algicices (3-[3-indolyl] butanoic acid) (Fortnum and Martin, 1998; Santos *et al.,* 2006). Some bactericides (triazolothiadiazine [0.5 to 12 mM, in solution] (Khanum *et al*., 2005), streptomycin sulfate [400 mg kg^{-1} of soil] (Lin *et al*., 2010) are also used. Calcium chloride is effective in reducing the *Ralstonia pseudosolanacearum* populations (Suseela *et al*., 2019). The use of antibiotics such as oxytetracycline and streptocycline shows good control over bacterial wilt. Carbendazim and copper oxy chloride also used against ginger wilt shows some reduction in the wilt incidence but it is less effective than antibiotics (Suseela *et al*., 2019). Application of chemical is very problematic to environment as the pesticide residue are persistent in the produce too (Dasgupta *et al*., 2007). These produce may cause some changes in the physiology of the consumers will lead to health issues.

Cultural methods are also used in managing bacterial wilt. In this, application of lime, biochar, intercropping, crop rotation and tillage are also used. Tillage is the first managing technique, it involve in breaking of hard land and exposing of inner soil to outer and vice versa. This should be done in summer to expose the soil to hot sunlight lead to death of pathogens. Lime ($CaCo_3$ or CaMg (CO3)2) application in bacterial wilt infected field shows a significant reduction in wilt incidence (Cao *et al*., 2022; Tafesse *et al*., 2021). Composting helps in reducing the wilt incidence due to the increase in population of beneficial microorganisms (Hoitink *et al*., 2001). Organic manure application increase the soil microbiome. Probiotics along with organic manure helps in creating antagonism against bacterial wilt causing pathogen (Mukta *et al*., 2017). Crop rotation with non host crops for a season helps in reducing the incidence of wilt by 13% (Lemaga *et al*., 2001). The consistent monocropping has led to an increase in bacterial wilt incidence (Niu *et al*., 2017). Intercropping of maize and beans helps in reduction of 55% disease incidence in potato cultivation (Chadfield *et al*., 2022).

Biological control is nothing but use of living organism to control another living organisms by using concepts like mutualism, antagonism, parasitism etc. (Sahu *et al*., 2017). There are lot of organisms are showing control over bacterial wilt, *Enterobacter tabaci* and *Bacillus cereus* new microorganism have been reported so far (Malek *et al.*, 2023). Bacteriophages (Álvarez and Biosca, 2017), *Flavobacterium anhuiense* (Jeong *et al.*, 2019), *Paenibacillus polymyxa* (Soliman, 2020), *Pseudomonas fluorescens* (Suresh *et al.*, 2022), *Pseudomonas protegens* (Rai *et al.*, 2017), *Stenotrophomonas maltophilia*, *Streptomyces sp.* (Adam *et al.*, 2023), *S. marcescens* (Mamphogoro *et al.*, 2020), *Pseudomonas putida* and *Streptomyces sp.* (Saputra *et al.*, 2020), Azotobacter (Sahu *et al.*, 2017) and *S. plymuthica* (Nguyen *et al.*, 2021), *Pseudomonas sp.*, *Paenibacillus peoriae* and *Bacillus licheniformis* (Bahmani *et al.*, 2021) were some of the micro-organisms used as a biological control. In these some of them are involved in developing induced systemic resistance (ISR) of plants (Compant *et al.,* 2005; Kloepper *et al.,* 2004). and some directly suppressing the pathogen by producing siderophores, HCN and antibiotics (Fernando *et al.,* 2006; Sayyed *et al.,* 2013; Jha and Subramanian, 2014).

Host plant resistance is effective and economic approach in lot of crops (Yuliar *et al.*, 2015). This approach involves screening for resistance in cultivars, varieties and some other grafting methods and biotechnological techniques also used. LYZ-C gene was inserted into potatoes by using vector *Agrobacterium tumefaciens* LBA4404. 16 transgenic clones were identified carrying the LYZC gene (Pasmawati *et al.*, 2021). Mutation breeding by gamma radiation helps in development of resistance in ginger against bacterial wilt because of its vegetative propagation method (Prasath *et al.*, 2011). In tomato, lot of resistant varieties are developed, they are BT118-4-1-1, BT-116-8-1-1, Tomato-415, Sonali (Sel2), DPT 38, VC 48, CRA 66 (Sel-A), BWR 1 (Asel. From VC 8-1-2-1), Sonali x SP-2-2, Utkal Pallavi, Utkal Deepti, BT12, BT 14, BT 18, Pusa Early Dwarf, Navodaya, Selection 7, Pusa Sheetal, Arka Abha, Arka Alok, EC386019, IC214633, EC386023, LA 2639A, LA 2691, 88 BWR, 83-211, 84 BWR, CR15955-223, D4 -22-0, Shakti, Swarna Lalima, Swarna Naveen, CHDT-1X, CHDT-180, CHDT-195X, CHDT-180, CHDT-4 x CHDT-1, (EC339074 x EC-386021), (Swarna x Sampada), BT-10, CKVT-17 and Sikkim local. Resistant varieties or cultivar of brinjal are Swarna Shyamli, Swetha, Swarna Pratibha, BB 64, JC 8, Arka Keshav and Arka Nidhi, Singnath, BB 40, BB 64 and Green round, Surya, Annapurna, BB-7, BB13-1, BB44, F1 hybrids Surya x SM-116, Arka Keshav x SM-71, Arka Neelkanth, 95-17, BB-46, CHES 243, IHR-12, IHR-21, IHR-54, B7, DPL-B1, SM-6-6, BB-60-C (Singh, 2017).

Physical methods which are very useful in managing the bacterial wilt includes soil fumigation, soil solarization and hot water treatment. Irrigation with cold water (nearly 4 to 20°C) has significantly decreased the bacterial wilt incidence (Tajul *et al.*, 2011). Hot treatment of infected for two days at 45°C leading to reduction of population from 2-7×10^{8} cfu to 0-115 cfu g^{-1} (Kongkiattikajorn and Thepa, 2007). Soil is sterilized by using trapping sunlight to increase the soil temperature to suppress the pathogens population (Kumar and Hayward, 2005).

Ralstonia solanacearum is a complex pathogen, due to that no one method alone cannot be useful in managing the pathogen (Yuliar *et al.*, 2015). By combining several approaches, it could enhance the efficiency up to 100% (Wu *et al.*, 2020). It should be managed by integrating cultural, physical, mechanical, chemical and biological methods. The disease occurrence is based on pathogen's virulence, host susceptibility and environmental conditions. Pathogen cannot be altered but by using resistant host and doing some modifications in the environmental conditions will reduce the wilt incidence.

Conclusion

Ralstonia solanacearum is ubiquitous soil borne pathogen with very wide host range and high diversity in their species makes them distributed all the world. Although they have ability to cause heavy yield loss, by prior diagnosis and prophylatic management. By avoiding yield loss, we can easily achieve our increased yield.

Future Perspectives

Development of fast, race specific detection methods for all the bacterial wilt pathogen.

Development of Screening techniques for pathogen in soil and planting materials. Findingout distribution of races of the pathogen all over the world. Identification and Production of resistant varieties against the pathogen. Determination of sustainable management strategy for the bacterial wilt.

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Effect of Crop Establishment Methods and Weed Management Practices on Growth and Yield of Transplanted Rice (*Oryza sativa* L.*)* Under Coastal and Saline Belt of West Bengal, India

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Abstract

A Field experiment was conducted to evaluate the effect of crop establishment methods and weed management practices on growth and yield of transplanted Rice (*Oryza sativa* L.*)* under coastal and saline belt of West Bengal at an Instructional Farm at Sasya Shyamala Krishi Vigyan Kendra, Arapanch, South 24Pgs, West Bengal during *kharif* season of 2022 in Split-Plot Design replicated thrice. Conventional and System of Rice Intensification were taken in main plot treatments and different weed management practices were taken under sub-plot treatments. Pretilachlor 1000 gm *a.i.* per ha followed by one hand weeding at 30 DAT behaving statistically similar with weed free plots resulted in significantly lower total weed count and total weed dry weight. Pretilachlor 1000 gm *a.i.* per ha followed by one hand weeding at 30 DAT recorded the highest grain yield which was at par with weed free plots followed by Pretilachlor 1000 gm *a.i.* per ha followed by Na-bispyribac 25 gm *a.i.* per ha at 2-3 leaf stages (15-25 DAT) and Pretilachlor 1000 gm *a.i.* per ha. SRI recorded the highest plant height, tiller per hill, effective tiller per hill, panicle length, grain yield and also B:C ratio. Ultimately the result revealed that Pretilachlor 1000 gm *a.i.* per ha followed by one hand weeding at 30 DAT along with combination with SRI was the best treatment combination for reducing total weed population and dry weight of weed and increasing grain yield in transplanting *kharif* rice.

Keywords : conventional, SRI, weed management, transplanted *kharif* rice

Introduction

Rice (*Oryza sativa* L.) is the most widely consumed staple food for more than 50% of the world's human population. Rice is relished as staple food by majority of the world's population – with Asia, Sub-Saharan Africa and South America the largest consume in regions. In this world, huge growing population is the most limiting factor to meet the world food security and the demand so sustainability. World rice production nearly doubled from the 1960s to the 1980, mainly due to the technological advances referred to as the Green Revolution. The Green Revolution comprised the replacement of traditional cultivars with modern cultivars and the increased use of external inputs that included mineral fertilizer, irrigation water and pesticides. The expansion of this technological package was facilitated by the political incentives to construct irrigation infrastructure and to subsidize chemical inputs. After the wide spread of the green revolution throughout irrigated paddy fields in Asia, however, the rice yield increase has slackened, reflected by the decline in the annual rate of rice yield increase from 2.7 % in the 1980s to 1.1% in the 1990s. As the population in rice growing areas is still expanding rapidly, the resumption of yield increases is vital. It is estimated that 40 % of more rice production will be required by 2030 to satisfy growing demand with no increases in cropping areas (Khush, 2005).

India is the second-largest rice producing country in the world where rice is the main staple food crop. In India, rice occupied 45 million hectares area with a production of 120 million ton and average yield 2.2 t/ha (Anonymous, 2020). The main and most common method of rice cultivation in India is conventional method of rice transplanting which consist of transplanting of 4-5 seedlings or more than that of 20-40 days old seedlings. Repeated puddling of land in the transplanting method has been encouraging tremendous complications such as destroying the soil physical properties, disintegrating the soil aggregates, by this means creating hardpans. Thereby cultivation for the succeeding crops going very problematic and less productive. Consequently, continuous pumping of ground water for repeated puddling in the field declining the ground water table and that will lay human life in danger.

In such a situation, the system of rice intensification was recently promoted as an alternative technology and resource management strategy for rice cultivation that may offer the opportunity to boost rice yields with less external inputs (Stoop *et al.* 2002; Uphoff and Randriamiharisoa 2002). The system of rice intensification consists of a set of management practices that were mainly developed through participatory on farm experiments in the central highland of Madagascar in the 1980s (Stoop *et al.* 2002). The main elements of SRI are: (1) early transplanting of young seedlings, 8-12 days old, (2) transplanting single seedlings with wide spacing, 25 cm x 25 cm or more depending upon soil fertility status, (3) mechanical weeding with a rotary push weeder that aerates the soil as well as it controls weeds, (4) water management in such a way that there is no continuously standing water during the vegetative growth phase, and (5) reliance on compost as far as possible, with supplemental or no use of chemical fertilizer (Uphoff and Randriamiharisoa, 2002).

Weeds are at present the major biotic constraint to increase rice production worldwide (Zhang, 1996). Weed infestation is regarded as one of the major causes of low crop yields throughout the world and can cause 50-60 % reduction in grain yield under puddle conditions and 91% yield reduction in non-puddled conditions (Ali and Sankaran 1984). Normally the loss in rice yield ranges between 15-20 % yet in severe cases the yield losses can be more than 50% depending upon the species and intensity of weeds. In Myanmar, weed infestation reduces the rice grain yield by 26 % in wet– seeded rice. The prevailing climatic and edaphic conditions are highly favorable for luxuriant growth of numerous species of weeds that strongly compete with rice crop.

Table 1. Predominated weed species found in experimental field

Sl no.	Grass (4)	Broad leaved (6)	Sedge (2)
1.	*Echinochloa colona*	*Ludwigia parviflora*	*Cyperus difformis*
2.	*Echinochloa crusgalli*	*Alternanthera sessilis*	*Scirpus atrovirens*
3.	*Digitaria sanguinalis*	*Alternanthera philoxeroides*	-
4.	*Panicum repens*	*Sagittaria sagitifolia*	-
5.	-	*Monochoria vaginalis*	-
6.	-	*Marselia quadrifolia*	-

With these perspectives the investigation on **"Effect of Crop Establishment Methods and Weed Management Practices on Growth and Yield of Transplanted Rice (*Oryza sativa* L.) under Coastal and Saline belt of West Bengal, India"** was carried out with the following objectives:

1. To study the effect of different crop establishment methods on growth and yield attributes of rice;

2. To evaluate the effect of different weed management practices on growth and yield attributes of rice;

3. To determine the interaction effect of Crop Establishment Methods and Weed Management Practices on growth and yield attributes of rice;

4. To observe the effect of crop establishment methods and Weed Management Practices on economics of rice.

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 year 2022. The soil of the 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 and a total 12 treatment combinations each replicated thrice. The rice variety '*Sabita*' (NC-492) was used in the experiment. The treatments are M_1: Conventional transplanting M_2: System of rice intensification (SRI) S_1: Weedy Check, S_2: Weed Free, S_3: Pretilachlor 1000 g *a.i.* per ha, S_4: Pretilachlor 1000 g *a.i.* per ha followed by one hand weeding at 30 DAT, S_5: Pretilachlor 1000 g *a.i.* per ha followed by Na-bispyribac 25 g *a.i.* per ha at 2-3 leaf stages (15-25 DAT), S_6: Na-bispyribac 25 g *a.i.* per ha followed by use of Cono Weeder at 45 DAT. 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

TABLE 2. Effect of crop establishment techniques and weed management practices on growth and yield attributes of rice

Treatments	Plant Height (cm)	CGR 30-45 DAT	CGR 46-60 DAT	CGR 61-90 DAT	Effective Tillers per hill	Panicle Length (cm)	Grains per Panicle
Crop establishment techniques							
M_1	139.24	10.01	12.05	4.12	8.92	23.64	272.33
M_2	158.81	10.15	15.04	6.59	10.41	27.74	320.50
S. Em (±)	1.97	0.90	0.46	0.40	0.31	0.54	7.90
CD at 5%	11.99	NS	2.78	2.46	1.54	3.26	48.06
CV (%)	8.87	—	7.15	16.40	9.74	4.42	5.65
Weed management practises							
S_1	129.1	5.42	8.69	2.24	7.81	22.13	262.35
S_2	157.93	11.50	17.71	7.11	11.20	27.78	324.00
S_3	135.84	7.56	11.58	4.15	8.26	24.38	274.00
S_4	156.79	11.00	17.01	6.74	11.00	27.78	323.33
S_5	150.78	8.43	13.78	6.09	10.43	26.42	303.33
S_6	142.72	7.57	12.49	5.04	9.50	25.72	290.67
S. Em (±)	1.95	1.18	1.12	0.68	0.31	1.10	12.01
CD at 5%	5.76	3.50	3.29	1.99	0.90	3.24	35.44
CV (%)	5.64	16.91	10.10	15.84	7.84	5.24	4.96

TABLE 3. Effect of crop establishment techniques and weed management practices on yield of rice

Treatments	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)	Seed Weight (g)
Crop establishment techniques				
M_1	2599.18	3945.54	39.21	2.97
M_2	2965.70	4607.35	39.74	2.98
S. Em (±)	60.04	108.31	1.44	0.01
CD at 5%	365.39	659.13	NS	NS
CV (%)	7.95	8.01	—	—
Weed management practises				
S_1	2475.39	3877.00	39.03	2.87
S_2	3068.63	4708.56	39.81	3.05
S_3	2545.89	3873.67	39.14	2.93
S_4	3062.89	4659.89	39.75	3.04
S_5	2861.18	4392.72	39.34	3.01
S_6	2680.66	4146.83	39.24	2.93
S. Em (±)	110.17	190.45	1.87	0.04
CD at 5%	325.01	561.82	NS	NS
CV (%)	6.57	7.12	—	—

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

From the said experiment it shows that 12 weed species were predominated during the season. Out of these 12 weed species 4 grasses, 6 broadleaved and 2 sedges were found in the experimental site. Among them *i.e.*, within the grasses *Echinochloa colona* followed by *Echinochloa crusgalli* were seen the most. Among the broadleaved weeds *Sagittaria sagitifolia* and *Marselia quadrifolia* were mostly seen and among the sedges *Cyperus difformis* was mostly observed on the borders of the plots.

Plant height, dry weight of crop and tillers hill^{-1} were significantly higher in all the crop growth stages by System of Rice Intensification (SRI) than the conventional system of rice transplanting (M_1).

Weed free plots registered the higher value of tillers per hill which was at par with application of Pretilachlor 1000 g *a.i.* per ha followed by one hand weeding at 30 DAT. However, Minimum tillers per hill were recorded by the weedy check plots for both the main plots.

Significantly higher number of total grains panicle^{-1} was noted under hand weeding twice (Weed Free plots) followed by the application of Pretilachlor 1000 g *a.i.* per ha followed by one hand weeding at

30 DAT. This was due to better suppression of weeds and weed free condition to the crop, resulting in higher weed control efficiency and higher rice yield attributes which ultimately resulted in higher grain yield as compare to weedy check.

The higher grain and straw yield observed under weed free plots over all the treatments followed by the application of Pretilachlor 1000 g *a.i.* per ha followed by one hand weeding at 30 DAT. This were attributed because of high weed control efficiency and availability of all crucial resources resulting in better growth and development of crop plants. Proper growth and development of plant promotes the assimilation to be translocate and accumulation of more dry matter in the upper part of the plant which ultimately increase the grain yield.

In these findings the maximum and minimum cost of cultivation and net return were noted under weed free and weedy check plots. But the application of Pretilachlor 1000 g *a.i.* per ha followed by one hand weeding at 30 DAT recorded highest net return and the benefit cost ratio.

Conclusion

Thus integrated use of SRI with application of pretilachlor @ 1000 g *a. i.* ha^{-1} followed by one hand weeding at 30 DAT was the best treatment combination for better weed management in transplanted *kharif* rice.

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Dry Direct Seeded Rice in *Boro* Season – Revitalizing Innovations in Sustainable Production Practices

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Abstract

Rice is one of the most widely consumed cereals and is widely grown all throughout the nation. Rice is traditionally grown using the puddled transplanting method, which yields a high and consistent yield. It has been established that the *boro* season is the best for crop management and improved yield. However, a lot of irrigation water is needed for the production when using the puddled transplanted method. Due to decreasing water supplies, we are becoming more and more water scarce. Although labor wages are rising over time, produce prices are not meeting projected returns. This poses a significant challenge to the farming of rice. One technique that may reduce the need for labor and irrigation water is dry direct sowing of rice. The dry direct seeded rice technique omits the steps of creating a seedbed, preparing puddled ground, keeping the land submerged using flood irrigation, removing seedlings, and relocating them into the main field. thereby bringing down the price of farming. Due to the breakdown of integrated weed and crop stubbles in the submerged state, puddled rice fields are also thought to contribute to greenhouse gas emissions. With the dry direct planting approach, the issue of greenhouse gas emissions from puddled rice fields can be readily resolved. Even if the field is kept in an aerobic state during this process, methane generation is inhibited. The construction of a hard pan in the subsurface layer is also attributed to the creation of puddles. This is preventing the recharging of groundwater, lowering river flow, and causing sinkholes and fractures to occur. With little work and the option of tillage, dry direct seeded rice is a simple way of seeding rice directly into the field. For more convenient seeding, consider using a seed cum fertilizer drill or drum seeder. Dry direct sowing was also discovered to shorten the rice's 7–10 day growing period. This opening up new possibilities for further agricultural intensification or multicropping. Lowland water scarcity locations can easily adopt dry direct planting, which is known to be traditionally used in upland water scarce areas. This method can provide a greater or equivalent yield as related methods when managed properly and operated at peak efficiency. It has been tried recently by certain persons, who claim to have had better yields with higher economic returns. In order to maximize agricultural productivity while avoiding negative effects on the environment and soil, this review examines the consequences of dry direct seeded rice during the *boro* season.

Keywords: Decreasing water supplies, greenhouse gas, higher economic returns, intensification, labour wages.

Introduction

A total of 47.58 million hectares are used for rice cultivation, yielding 135.75 million tons of grain. (Statista, 2024). The main technique for producing rice in India is to transplant the seedlings into puddled land. Transplanting has a number of benefits, including increased nutritional availability (iron, phosphorus, zinc, etc.) and improved weed flora suppression (weed flora suppresses crop weed competition). However, under the plough zone, puddling leads to the development of hard pan. This results in decreased water permeability, which prevents groundwater from replenishing. Major obstacles to the transplanting process include soil erosion, paucity of irrigation water, and environmental deterioration. Even though transplanting requires a lot of effort and labour wages are rising daily, marginal farmers find it difficult to make ends meet. Additionally, transplanting results in significant water loss through evaporation and percolation, accounting for around 80% of freshwater resources.(Dawe *et al.*, 1998).

Significant amounts of groundwater are extracted for irrigation, which lowers groundwater tables and reduces river flow. This allows sinkholes and fissures to form, endangering the ecosystem. (BADC, 2006). By 2025, 39 million hectares of irrigated rice in Asia are predicted to experience "physical water scarcity." It's also possible that the lack of water may cause a 30% decrease in productivity by 2050. (Siddique and Hossain, 2015).

The lack of labour, water, and recent technological advancements are making direct seeding techniques more and more appealing. (Velasco and Pandey, 2002). Rice can be directly seeded using two techniques. These two methods are dry direct seeding and moist direct seeding. Wet direct seeding reduces labour requirements when transplanting, while dry direct seeding is more suitable for regions experiencing a shortage of both labour and water. (Pandey *et al.* 2002). These days, it is believed that direct-seeded rice can yield a higher financial return with appropriate management. (Mitra*et al.*, 2005). A rice-growing technique known as "dry direct seeding" involves physically sowing rice onto dry ground at a moisture content just right for germination. (Joshi *et al.*, 2013).

While dry direct seeding rice has shown promise in terms of labour and water savings, the main drawback of this technique is yield losses due to weed development occurring at the same time as the crop. Yield losses in DDSR can reach 75%, or around 30% of the overall cost of production. According to (Rao *et al.*, 2007).

The primary emphasis of this review is the potential of dry direct seeded rice in controlling labour and water scarcity while maintaining environmental quality in the production of *boro* rice.

Dry direct seeded rice (DDSR)

The seeds are sown using this technique on a dry bed that has not been puddled. The environment used for seed sowing is aerobic, which is why it is called DDSR. This technique has historically been used in Asia's lowland, rain-fed upland, and flood-prone areas. (Rao *et al.*, 2007). There are various establishing techniques in DDSR, one of which is dispersing seeds over bare, untilted soil. utilising a dibbler to sow seeds on prepared ground. utilising a seed cum fertiliser drill to plant seeds into properly tilled or zero-tilted soil. These days, this technique is widely used in places where water is becoming scarce. Drilling seeds is preferred over broadcasting in DDSR because it allows for better row management, makes it easier to control weeds between rows, requires less seed for line sowing, and requires less labour and time.

Cultivation practices of DDSR

DDSR primarily involves seeding dry land in order to reduce irrigation losses and farming expenses. Additionally, DDSR seeks to maintain yield across a shorter time frame to enable intense or multicropping. The main consensus was that DDSR produced a lower yield than conventional rice farming. It can be the result of subpar management techniques. Few management procedures must be followed for a crop establishment to be successful.

Land preparation for DDSR

In certain uplands, dry land preparation has historically been used. However, more recent founding has demonstrated that lowlands can also use it. As a result of our customary puddled rice transplanting, a hard pan is gradually forming in the subsurface layer. In addition to regulating the recharging of ground water, it also lowers river flows and promotes the development of sinkholes and fissures. There is no need to keep standing water in the field or puddling while using the DDSR approach. There are two options for after seeding: minimal or no tillage. Additionally, this method uses less labour, which lowers the initial cost.

Seed sowing

The uprooting and transplantation of

transplanted rice requires a significant amount of work. However, seeds can be disseminated into the field with ease in DDSR. For that purpose, about 60–80 kg of seed is sufficient. Nevertheless, with the aid of a seed cum fertiliser drill, planting and fertiliser application can be completed simultaneously, even though broadcasting needs a larger seed rate and does not maintain adequate plant spacing. A farmer working alone can readily finish a larger area of land using this strategy. It is simple to maintain appropriate spacing and adhere to weed management when utilising a seed drill. (Singh *et al.*, 2008).

Weed management in DDSR field

When rice is transplanted into puddles, the ground is submerged in standing water, which largely gives the crop an edge against weeds. However, with DDSR, weed grows more easily even when the crop begins its journey after it. In crop-weed competition, the first 30 to 50 days are critical and can result in significant losses if improperly handled. As a result, stale seedbed preparation can be used to manage weeds in DDSR fields. To monitor weed development in between rows, a mechanical conoweeder can be employed.Chemical pesticideusecan offer more effective weed control. (Singh*et al.*, 2008).

Water required by the rice cultivation

Water is needed for seepage and percolation losses, evapotranspiration, and ground preparation in traditional rice farming. However, the only water required in reality is what crops require to grow and evaporate through evapotranspiration. In actuality, the plant doesn't require much water. Through other losses, the maximum water resource is lost. (Hafeez *et al.*, 2007). The amount of water needed for rice farming varies depending on the kind, soil, climate, and management techniques. The average amount of water needed is between 470 and 2650 mm. (Yadav *et al.*, 2011). When compared to transplanted rice that has been puddled, dry direct seeded rice uses about 50% less water. (Lampayan*et al.*, 2004). Water loss prevention techniques such as seepage and percolation during crop growth are part of DDSR. (Castaneda *et al.*, 2002).

Economic issues that occur due to high labour requirement

When preparing the puddled condition and transplanting the seedling, the traditional method of rice transplanting necessitates a large amount of effort. Meeting demand during crop setup is challenging due to recent increases in labour costs and the demand in non-agricultural businesses. (Drew, 2005).

The steps of nursery growing, uprooting seedlings, preparing a puddled condition, and transplanting are omitted using the dry direct seeding method. While DDSR only reduces the amount of effort needed, the traditional approach is extremely labour-intensive. According to research, DDSR can reduce the need for 11–66% of labour inputs and 35–57% of irrigation water (Bhushan *et al.*, 2007; Jat*et al.*, 2009; Kumar *et al.*, 2009). It has been discovered that DDSR improves labour and water management while also being more economically advantageous. (Khade*et al.*, 1993). It has been discovered that DDSR can reduce production costs over puddled transplanted rice by roughly 11.2%. (Mitra*et al.*, 2005). (Wong and Morooka, 1996) discovered that the DDSR approach saved roughly 29% more money than puddle transplanted rice. Additional cost savings could be attained by implementing alternative low-cost weed control strategies.

To minimize the global issue arising with greenhouse gas emission

In a rice field, transplanted rice techniques keep the water stagnant. This results in the production of three significant greenhouse gases as well as the breakdown of integrated weeds and stubble. Methane, nitrous oxide, and carbon dioxide are the main greenhouse gases that are created. Gases make up 39%, 1%, and 60% of the total. (OECD, 2001). Rice that has been transplanted produces a lot of methane because it limits the oxygen supply and induces anaerobic conditions. (Houghton*et al.*, 1996). In the DDSR field, submerged conditions are avoided and water is not maintained continuously. DDSR has reduced methane emissions as a result. (Joshi *et al.*, 2013). The redox potential, alkalinity, pH, texture, and other characteristics of the soil affect how much methane is emitted. (Aulakh*et al.*, 2001). Because of the microbial nitrification and denitrification processes, aerobic conditions can partially enhance the release of nitrous oxide while reducing the emission of methane. (Malla*et al.*, 2005). In order to reduce the emission of both CH_4 and N_2O, water management should be done in a way that maintains the soil redox potential at an intermediate range (100 to 200 mV). Therefore, it is possible to view dry direct seedling as a significant method of lowering greenhouse gas emissions (Corton*et al.*, 2000; Wassmann*et al.*, 2004).

To check environmental sustainability issues

Puddled rice farming using the traditional method necessitates heavy watering, particularly during the boro season. Massive amounts of groundwater must be extracted in order to meet the needs for water. Rainfall is necessary to recharge the groundwater reserves. Seepage loss and evaporation simply squander a vast amount of applied water. A plant can only absorb a small amount of water. It follows from rice physiology that it doesn't need a source of stagnant water. Because arenchimata tissues are present, it can withstand standing water. The energy that a plant expends to hold onto air within its tissues may be utilised to grow crops. The puddling creates a hard pan that regulates the recharging of ground water. reduces river flow as a result, which causes sinkholes and fissures to occur. This is resulting in major issues including the saline development and heavy metal pollution. Shallow aquifers that are less than 100 metres deep are the primary source of groundwater with high concentrations of arsenic (As) (Qureshi *et al.*, 2014). The amount of arsenic in rice grains is significantly influenced by the water management system. Arsenic buildup in rice can also have a detrimental effect on rice yield and increase the concentration of arsenic in rice grains, which puts consumers' health at risk. Grain arsenic content was found to be lower under aerobic (dry) conditions than under anaerobic (flooded) conditions (Daum*et al.*, 2001). Therefore, to eliminate arsenic issues, water-saving aerobic rice cultivation should be carried out in the arsenic-affected area (Yamane *et al.*, 1976; Maejima*et al.*, 2008; Sarkar *et al.*, 2012).

Development of new techniques like crop intensification and diversification

One of the main ways that DDSR reduces production costs is by conserving labour and irrigation water. In addition, the DDSR permits adding one or more crops to the cropping system. Short-duration rice varieties that are planted early will enable early crop harvesting and allow for the growth of another crop. As a result, DDSR permitted double or triple cropping of transplanted rice as opposed to only one. (Van My *et al.*, 1995; Pandey and Velasco, 2002). DDSR faces an infestation issue with weeds. As a result, a specific quantity of herbicides must be used. Farmers were assisted in switching to DDSR by the development of new short-duration cultivars and new herbicides with potential for improved weed control. Anwar *et al.*, 2012a,b; Mortimer *et al.*, 2008; Pandey and Velasco, 2002; Arefin*et al.*, 2018; Rahman *et al.*, 2017; Juraimi*et al.*, 2013). In the first 30 to 50 days of a rice harvest, weed competition is the greatest obstacle. Following that period of time, intercropping might readily resolve the issue. Infestation of weeds will decrease. Crop diversity and intensity are also increased by intercropping. The overall return from the same plot of land can be increased using this technique. Additionally, this makes better non-chemical weed control possible. According to certain reports, intercropping yielded higher results than using rice alone (Sarma and Shyam, 1992). It has been reported that growing DDSR rice alongside other veggies boosts the net return. (Rabeya*et* al., 2018).

Results of adopting direct seeded rice

Gurpreet Singh used the DSR approach to cultivate 51 q/ha of basmati rice on 5 acres in the Faridkot district of Punjab, compared to 46.3 q/ha from his transplanted rice. According to his estimate, there is a savings of approximately 3000-4000 rupees per hectare due to decreased manpower costs and a lower necessity for irrigation (7 irrigation is less). Inspired by such, he increased his DSR area by double in 2013–14. (Prasad *et al.*, 2014).

Current advantages and constrains of DDSR technology

Advantages

i. Almost similar yield retention like transplanted rice in optimum condition.

ii. Saving of up to 20-30% of irrigation water.

iii. Saves up to 35 to 40-man days/ha.

iv. Reduced cultivation time (7-10 days earlier maturity) and cost. (Prasad *et al.*, 2014).

v. Enhanced potential of fertilizer while using seed drill.

vi. Low amount of greenhouse gas emission.

vii. Provides minimal disturbance to soil structure.

Constrains

i. It still requires higher seed rates.

ii. Direct seeding causes the seeds are exposed to Pest and Bird attacks.

iii. Lower plant depth causes risk of crop lodging.

iv. Increased emission of N_2O due to aerobic condition.

v. The concurrent growth of weed and crop needs better attention to weed management.

vi. Lower availability of nutrients like Ca, Fe etc.

Future scopes

DDSR with proper management is promising high economic return and proper conservation of available resources. DDSR is more popular in *boro* rice cultivation of Chhattisgarh, Odisha and Andhra Pradesh. There is a scope for upscaling the technologies in the north-west Indo gangetic plains. (Prasad *et al.* 2014).

Conclusion

Day by day our available resources are become scarce. Lower availability of irrigation water and increasing labour wages are becoming potential threats for rice cultivation. Puddled rice condition also emits higher amount of greenhouse gas and accumulation of heavy metals in crop. Puddling also causes formation of hard pan that checks proper ground water recharge. It causes formation of cracks and sinkholes and lowering the river flow. Nowadays field preparation using puddled transplanting method also requires high amount of diesel for the machines. At this situation DDSR can provide a good economic return while promising sustainable use of available resources.

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Double Transplanting: A Climate-Resilient Practice for Rice Production

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Abstract

The rivalry between population growth and food supply could lead to severe food insecurity as a result of climate change. Climate factors such as temperature fluctuations and unpredictable rainfall have a major impact on crop output.The habitat where rice is grown has been discovered to be impacted by variations in climate. One of the biggest threats to low-lying areas where rice is grown is flooding.Frequent flooding reduces farm income, which deters farmers from experimenting with new technology. Double transplanting is the process of transplanting rice seedlings from a primary nursery to a secondary nursery then back to the main field. According to scientists, this method results in healthier, taller seedlings that are more resilient to environmental challenges like deep water when transplanting. The main benefit of this approach is that it allows for flexible late transplanting during the rainy season. When it comes to the seasonal pattern of rainfall, rice growers can transplant rice in their primary plot per field at a favorable period.In low-lying, flood-prone places, it is a contingent technique to maximize production. Due to climate change, Eastern India has severe droughts and floods in recent years, which has resulted in crop loss. A climate-resilient technique for low-land rainfed rice ecosystems is double transplanting. Despite requiring more labor, this approach lowers production costs by decreasing weed infestation, comparatively lowering the incidence of insect pests and diseases, and requiring less water, fertilizer, and pesticides because seedlings are maintained across a smaller area.

Rice, the "Global Grain", is produced in 89 countries and provides food for almost half of the world's population. In certain places of Asia, rice has been farmed for 6,000 years. India's nutrition, economics, and culture are significantly influenced by the rice crop. According to Pathak *et al.* (2018), India leads the globe in both rice production and area. The top producing states in India for rice are Punjab, West Bengal, Andhra Pradesh, Uttar Pradesh, Chattisgarh, Odisha, and Bihar, among others. According to IRRI (2016), in order to meet demand, world production of rice will need to increase from its present level of 493 Mt to 550 Mt by 2030. With a production of 86.0 million tonnes and an acreage of roughly 44.6 million, it is the mainstay of India's food production, accounting for 20 to 25 percent of the country's agricultural GDP and ensuring food security for over half of the country's population (Anonymous, 2002). However, by 2025 and 2050, our nation's rapidly growing population may stabilize at 1.4 and 1.6 billion, respectively, requiring 380 and 450 million tonnes of food grains annually (Thiyagarajan *et al.*, 2001).

Effects of changing climate and flood in India-

Because of the competition between population increase and food supply, the changing climate may result in significant food insecurity. Crop productivity is significantly influenced by climate variables as rainfall and temperature (Abbas and Mayo, 2021; Pickson *et al.*, 2020). Temperature and rainfall patterns are changing due to climate change, which has an impact on how crops evolve (Hussain *et al.*, 2020; Sridevi and Chellamuthu, 2015). Variations in rainfall and temperature have a negative impact on the phases of rice growth, which reduces rice output (Parry *et al.*, 2013). Reduced photosynthetic capacity, enhanced respiratory processes, shorter growth phases, elevated heat stress during important reproductive stages, and higher water requirements for rice production are the main causes of crop output losses (Abbas and Mayo, 2021; Ullah, 2017). Due to frequent submergence, flash floods affect about 16% of the world's paddy area (Dar *et al.*, 2018). Climate variations have been found to have an impact on the environment where rice is produced (Duncan *et al*., 2017). Floods are the main threat to agriculture in India, where they affect about 33% of the cultivable land (Ranuzzi and Srivastava, 2012). High yielding rice and wheat varieties were brought about by the Green Revolution in an effort to establish self-sufficiency and boost food production. As a result, hunger and poverty in the irrigation areas were lessened (Nelson *et al*., 2019). One of the main climatic instances that severely limits rice output in India with climate change is flooding. Nearly 50% of the crop is lost when submerged in water for more than a week, as most paddy types can tolerate (Nguyen, 2012). However, 100% of the harvest will be lost if the paddy crop is submerged for 14 days (Ismail *et al*., 2013). Roughly 80% of the paddy-producing regions in Eastern India have rainfed conditions, meaning that either an abundance of rainfall causes flooding or a deficiency of rainfall causes drought (Aryal *et al*., 2019). The crop is submerged in about 27% of Odisha's paddy-producing areas and 40% of Bihar's and West Bengal's. With an average yield of just 0.5 to 0.8 t/ha, flash floods constitute a risk for nearly 30% of India's paddy land (Bhowmick *et al*., 2014). India grows paddy mostly during one season (*kharif*), especially in the states of Assam, Chhattisgarh, Jharkhand, and Odisha. In the eastern portion of the nation, some farmers leave their arable land fallow due to the regular occurrence of floods (Singh *et al*., 2016).Frequent flooding reduces farm income, which deters farmers from experimenting with new technology and from implementing new varieties (Dar *et al*., 2017). Extreme weather occurrences have a greater negative effect on these farmers. Given the negative effects and vulnerability of agriculture to climatic pressures, new research is now greatly prioritized.

Double transplanting-

Relocating rice seedlings from a primary nursery to a secondary nursery and then back to the main field is known as double transplanting. Compared to the main nursery, the secondary nursery needs a comparatively bigger space. This is not how it is usually done, which is to raise seedlings in a nursery before transplanting them onto the main field. Indian farming was largely relied on farmers' indigenous technological skills. According to Chetry and Belbahri (2009), indigenous knowledge is the knowledge of people who are native to a certain geographic area and have their own language, culture, tradition, beliefs, folklore, rites, and rituals. To avoid crop failure caused by submergence, farmers use double transplanting strategy for rice. Seedlings that are one month old are moved with dense transplanting to a different field, and once the flash flood risk has passed, they are moved back to the main field. According to scientists, this method results in healthier, taller seedlings that are more resilient to environmental challenges like deep water when transplanting (Rautaray, 2007; Ashim *et al.,* 2010). However, the system's productivity would be reduced, and expenditures would increase.Farmers in some flood-prone areas engage in double or even triple transplanting in order to grow taller seedlings for transplanting in standing water at the start of the season (as in Bangladesh and India) or to rejuvenate seedlings while they wait for the floodwaters to recede enough to permit transplanting in the main field. Proper management of seedlings in nurseries or following transplanting in the field is also part of this practice (Ram *et al*., 2010). Additionally, it is claimed that double transplanting rice yields a higher yield than regular transplanting of seedlings of the same age (Satapathy, 2015).

The double transplant procedure is most common in Bangladesh, Bihar, West Bengal, Meghalaya (Garo Hills region), Assam, and Eastern Uttar Pradesh (Ballia, Gazipur, Mau, Varanasi, and Chandauli districts). There are several names for this technique that vary from one country and one region to the next. It is commonly referred to as the Ballan system in Assam, the Changginigeani in Meghalaya, the Kharonha in Bihar, the Kalam or Sunda in eastern Uttar Pradesh, and the Balon system in Bangladesh. Sometimes the window for transplanting is very large, extending from early July to late August because of the unfavorable moisture/water level in the field during the early part of the growing season. Due to overcrowding, nutrient deficiencies, and the prevalence of diseases like brown spot and leaf blast, seedling health cannot be maintained in the same nursery in a delayed planting setting for two to three months. Thus, double transplanting is desirable as contingent measure in flood prone lowlands of eastern India.

Varietal selection in double transplanting-

Not every rice variety is appropriate for double transplanting. Double transplanting is not recommended for cultivars that are short duration photosensitive. These cultivars enter reproductive stage at a specific period after sowing. Furthermore, in the short-duration double transplanted cultivars, the crop stand is less dense. Due to the shortened period available for tiller formation, planting older seedlings produces fewer tillers than early seedlings, which in turn produces a lower crop yield. Thus, double transplanting is appropriate for photoperiod-sensitive rice cultivars with a long duration (150 days). Double transplanting is frequently used to grow the following cultivars: Monoharsali, Kehol, Resu, Barut, Tipi, Jabilin, Kochugisim, Swarna, Ranjit, and Swarna sub 1.

Nursery managemen and transplanting methods-

In double transplanting, the seed requirements (35–40 kg/ha) is much less than when transplanting rice conventionally (60 kg/ha). First, at the primary nursery (Bechan bari in Assam), seeds are densely distributed according to this method. After four weeks, the primary nursery's seedlings are pulled up and moved (9 to 10 seedlings/hill) to a secondary nursery (known as Bolon bari in Assam locally), where they are spaced closer together (7–10 cm apart) and fertilized sparingly. The secondary nursery, also known as Dhan bari in Assam, is kept up like a primary rice field. To care for the seedlings, chemical fertilizers and insecticides are applied.The seedlings from the secondary nursery are then removed and moved to the main field after three to four weeks, by which time they are tall and the risk of flooding has passed. There is also less chance of consecutive days of heavy rain, and even in that case, the tall seedlings won't be flooded. Double transplanting prevents transplanted seedlings from being submerged in heavy rain during the peak of the monsoon. To ensure that no land is wasted, sparse transplanting is also done in the primary and secondary nurseries at the time of the final transplanting. The extra labor needed for land preparation, uprooting seedlings, separating seedlings, and transplanting makes this system's labor need slightly greater.The cost of production goes up due to the increasing labor needed. However, the lower amount of seeds, fewer irrigations, lack of weed control, and higher yields from double transplanting method compensate for the increased labor cost for double transplanting. Since seedlings primarily rely on seed reserve during the early growth stage, fertilizers are not applied in the initial nursery (Yoshida, 1981). Up to the third leaf stage of growth, rice seedlings could be supported by the nutrients saved in the seed (Hoshikawa, 1975). Additionally, during the first stage of nursing, the seedlings can consume some of the nutrients that are readily available in the nursery medium for future growth. Fertilizers are therefore only used in the second nursery.Improper nursery management techniques might have an impact on the growth of seedlings. If the seedlings are not tall enough to tolerate loose soil and high water levels both during and after transplanting, the final transplantation must be postponed. Furthermore, postponed transplanting has a negative impact on grain output, particularly as medium-term maturing high yielding rice cultivars. When seedlings older than 45 days were moved from a double nursery, the grain output was greatly decreased (Anon, 1984).

Methodology involved in double transplanting-

In this approach, seeds are initially densely dispersed in the primary nursery, and then 3 to 4 week old seedlings are transplanted in bunches (4-5) with narrower spacing (7-10 cm apart) in a secondary nursery. After 3 to 4 weeks, rice seedlings from the secondary nursery are pulled and clones transferred onto the main field (Das, 2006). Transplanting seedlings from primary to secondary nursery can mitigate the negative impact of older seedlings (Sarma *et al.*, 2010). In addition, this technique promotes the growth of taller, healthier seedlings that are more resilient to challenging circumstances such as deep water when transplanting (Rautaray, 2007; Ashim *et al.*, 2010). Additionally, Ziagun (2000) noted that double transplanting in rice increased output. To ensure there is enough water for the growth of rice seedlings, the first nursery is built on the low area. After 30-35 days, the seedlings are transplanted at 0.4 meter intervals in all directions to the second nursery, which is lower than the first nursery but higher than the main part of the rice fields. Transfer seedlings approximately 30 days old from the seedbed to a relatively high level field with thick transplanting, then to the main field when the seedlings are tall and the risk of flooding has passed. The main benefit of this approach is that it allows for flexible late transplanting during the rainy season. When it comes to the seasonal pattern of rainfall, rice growers can transplant rice in their primary plot per field at a favorable period. In the event of successive days of heavy rainfall in August through mid-September, the medium-to low-lying rice land parcels are usually drowned. Because of the possibility of submergence and the insufficient seedling height, this type of land is not ideal for transplanting young seedlings straight from the seedbed to the main plot.Under the double transplanting approach, mature tall seedlings are transplanted to low-lying rice fields late in the season, when the likelihood of consecutive days of heavy rains is low, and the tall seedlings are not submerged. As a result, during the height of the monsoon season, this technique of crop planting helps prevent rice plants from becoming submerged due to uneven rainfall distribution.

Reason behind higher crop yield under double transplanting over single transplanting of aged seedlings-

***a) Ensure optimum crop stand**:* Young seedlings die at a higher rate in unfavorable meteorological conditions (drought/flood). In contrast, taller and older seedlings under a doubly transplanted system withstand harsh environments better than younger and single transplanted seedlings. When transplanted or shortly after, seedlings grown using this technique are taller, healthier, and more capable of overcoming the deep water.

b) Transplanting of healthy seedlings: Seedlings that have been doubly transplanted have thicker culms and better food reserves. A thick culm keeps rice crops from lodging, and improved food reserves enable the plants to endure extended periods of waterlogging.

c) Reduced competition of growth factors (water, nutrient, light): The competition for growth factors are drastically reduced under double transplanted system compared to conventional transplanting. Which intern reduces the chaffy grains (unfilled grains/panicle) and increases panicle weight and grain yield.

d) Minimum weed competition/growth: Due to less competition between plants in secondary nursery, seedlings had more shoot length, root length and volume than seedlings Tall healthy seedlings suppress the weed growth better than short young seedlings.

e) Reduced insect pest and disease infection: Insect pest and diseased seedlings are omitted at the time oftransplanting. Which prevents thefurther multiplication of disease andother pest.

f) Better aeration:Wide spacing and proper water management provide suitable micro climate for standing rice crop.

g) Higher nutrient use efficiency: The loss of nutrients especially nitrogen is greatly reduced under double transplanted system due to controlled water management. The plants under the double transplanted plots are usually healthy, have longer panicles and more filled grains than the plants on the single transplanted parcels.

Disadvantages of double transplanting-

The double transplanting methodology is deemed inefficient in rice establishment when compared to the single transplanting strategy, according to Bangladeshi biological scientists that study rice. They contend that in the double transplanted field, the crop stand would be less thick, leading to a lower crop yield, since the older seedlings would have less time than the younger seedlings to develop tillers in the field. Additionally, the additional labor costs for transplanting in the secondary nursery field—which can be avoided under the single transplanting system—would drive up the cost of rice production in multiple transplanted systems. Therefore, rice cultivation would be less profitable using the twin transplanting approach. Bold rice straw produced from double transplanting cultivation system is not good as cattle feed. Also this system is not convenient for the big farmers because many plots need to be transplantedtwo times.

Farmer's experience-

According to the farmers' observations, the plants under the double transplanted plots are typically healthier than the plants on the single transplanted parcels, with longer panicles and more full grains. To guarantee consistent crop stand under both approaches, they modify the spacing while transplanting (older seedlings are transplanted more densely than younger seedlings). They lower the cost of intercultural operations by avoiding the need for additional crop care in the main field by using pesticides and weeding in the Bolon plot, which is one-eight the size of the main field. The producers claim that this approach has far fewer illnesses and pest infestations than a single transplanting system. However, farmers can avoid a labor shortage if they all transplant rice at the same time following the start of heavy rains that permit puddling of the main field. This is because the timing of the transplantation is staggered, with single transplanting on high land early in the season and double transplanting on low land late in the season. It facilitates the longer-term use of family labor, lowers the need for hired labor, and eases pressure on the labor market. As a result, the Bolon system seems to be a suitable technological solution developed by farmers to deal with this adverse (high rainfall) climate.

Conclusion-

In the flood-prone rice habitat, double transplanting is a suitable technological solution to prevent submergence problems. In low-lying, flood-prone places, it is a contingent technique to maximize production. Due to climate change, Eastern India has severe droughts and floods in recent years, which has resulted in crop loss. A climate-resilient technique for low-land rainfed rice ecosystems is double transplanting. Despite requiring more labor, this approach lowers production costs by decreasing weed infestation, comparatively lowering the incidence of insect pests and diseases, and requiring less water, fertilizer, and pesticides because seedlings are maintained across a smaller area.Farmers benefit from implementing the double transplanting approach for crop establishment, as evidenced by increased productivity and a noteworthy net return from rice farming. However, recent study conducted by farmers' fields and research institutes shown that double transplanting, particularly in low-lying locations, provides yield advantage over conventional approaches. Therefore, rather than dismissing the system, rice experts should focus on improving it by creating suitable varieties and other crop management techniques.

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