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Root Growth, Nutrient Uptake, Nodulation and Yield of Summer Mung [*Vigna radiata* (L.) Wilczek] as Influenced by Land Configuration and Varying Nutrient Management Practices under Coastal Plains of Odisha

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ABSTRACT

Background: Green gram being an important legume crop, its rooting traits and nodule characteristics are vital in determining its overall productivity. Land configuration plays a crucial role in influencing the root and nodule growth in green gram. Judicious use of balanced nutrients and fertilizers is needed owing to the sustainability concern of the environment and also for optimising the production process.

Methods: Field experiments were carried out at the Agronomy Main Research Farm, O.U.A.T. Bhubaneswar, Odisha, India during 2020 and 2021 to study the effect of different land configuration methods and varying nutrient management practices on the root growth, nutrient uptake and yield of summer mung. Split-plot Design was adopted with three replications having four main plot and 6 sub-plot treatments.

Result: The outcomes of the experiment showed that raised bed method with PDM-139 cultivar gave the highest pooled root length (13.1 cm), root dry weight (1.52 g) and shoot: root ratio (6.83). F6 nutrient management treatment gave synonymous results (12.16 cm root length, 1.53 g root dry weight). Similar trend was observed for number of nodules (15.48 nodules/plant) and nodule fresh weight (25.50 g) under land configuration, variety and (16.61 nodules/plant, 25.50 g) under nutrient management respectively. The total nutrient uptake in grain and straw for nitrogen, phosphorous and potassium was found to be the highest in flat-bed method with PDM-139 cultivar. The result revealed that sowing of green gram on raised bed land configuration with PDM 139 along with nutrient management practice based on STCR equations (F6) significantly produced more yield (522.84 kg/ha and 455.29 kg/ha respectively) than the other treatments. The study revealed that there was positive correlation between the grain yield and the respective N, P_2O_5 and K_2O uptakes.

Key words: Green gram, Land configuration, Nutrient management, Nutrient uptake, Root traits, Yield-uptake correlation.

INTRODUCTION

Greengram [*Vigna radiata* (L.) Wilczek] or 'Mung' or 'Mungbean' is one of India's oldest and most widely cultivated leguminous crops. Although it is generally a crop for the rainy season, early maturing types have shown to be a perfect crop for the spring and summer. Approximately six million hectares are currently under cultivation worldwide, the majority of which are in Asia (Sharma *et al.*, 2019). Being a legume, the crop greatly enhances soil fertility and the sustainability of agricultural systems by fixing the majority of its own nitrogen needs.Mungbean contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamin (Sarker *et al.*, 2012). It can be cooked or consumed whole. Additionally, it includes high-quality tryptophan (60 mg/g N) and lysine (4600 mg/g N) and is used for table purposes in the form of dal as well as whole grains. Since greengram is supposedly simple to stomach, patients favour it. Greengram sprouted seeds are a good source of thiamine, riboflavin and ascorbic acid (vitamin C) (Chaudhary *et al.*, 2003).

Green gram being a legume, the root nodulation and the rooting traits are of prime importance. Studies have shown that land configuration tends to have a considerable effect on the aforesaid characteristics. Green gram is commonly established by sowing seeds on flat surfaces, which frequently results in surface compaction and excessive soil moisture conditions that can occasionally have an impact on plant growth. By changing the physical

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environment of the soil, land configuration can play a significant role in contributing to higher population through uniform and unimpeded germination (Rath and Gulati 2020).

A balanced and suitable use of nutrients is now necessary due to the rising expense of fertilisers and the sustainability problems brought on by the excessive and careless use of chemical fertilisers. Bio-inoculation has been found to be a novel approach for improving the below ground plant traits, higher rhizosphere P-availability in case of Phosphorous solubilising Bacteria. Rhizobia can produce auxins to enhance cell division, differentiation, root growth and increase nodule formation. Odisha soils are predominantly acidic in nature (Mishra 2005). It reduces the availability of phosphorus due to its fixation as aluminium and iron phosphate. PSB/PSM can solubilize fixed phosphorus (He *et al*., 1997). Thus, it was worthwhile to plan a study on effect of these variables on the root traits, nutrient uptake and yield of summer green gram under coastal plains of Odisha.

MATERIALS AND METHODS

The experiment was conducted during summer season of 2020 and 2021 at the Agronomy Main Research Farm, O.U.A.T. Bhubaneswar, Odisha Bhubaneswar is situated in the east and south eastern coastal plain Agro-Climatic Zone of Odisha. at 20°15′N latitude and 85°52′ E longitude with an altitude of 25.9 m above mean sea level. The soil of the experimental site was sandy loam having pH 5.5, organic carbon 0.75 %, available nitrogen 225.5 kg ha^{-1}, available phosphorus 45.6 kg ha^{-1} and available potassium 129 kg ha^{-1}. The experiment was laid out in Split-plot Design with three replications and net plot size was 5 m × 4 m. There were four main plot treatments having a combination as of two land configuration (M1-flatbed method and M2- raised bed method) and two varieties (V1- Nayagarh local and V2-PDM-139). Sub-plots were allotted with six nutrient management practices like F1= Farmer's Practice (100 kg DAP ha^{-1} + need based plant protection), F2= F1+ seed inoculation with Rhizobium + PSB soil application, F3 = F2 + lime @ 5q ha^{-1}, F4 = F2 + NPK as RDF *i.e*. 20-40-20 kg NP_2O_5 -K_2O ha^{-1} (no flat application of DAP), F5 = F2 + Soil test based NPK application, 25-40-25 kgN-P_2O_5 - K_2O ha^{-1}, F6= F2 + STCR based NPK application. The different treatment denotations are represented in Table 1. Under STCR (F6) variety wise doses were arrived using following equations keeping a target yield of 6 and 8 q ha^{-1} for the variety Nayagarh local and PDM-139, respectively.

FN = 11.48 T-0.51 SN

FP_20_5 = 8.76 T-0.76 SP2O5

FK_20 = 12.21 T-O.51 SK20,

Where,

T- Target yield,

SN- Soil nitrogen value.

Accordingly, the dose for the variety V1- Nayagarh local and V2-PDM-139, the dose was worked as 5:22:7.5kg N-P_2O_5-K_2O ha^{-1} and the seeds were treated with fungicide, carbendazim @ 1.5 g kg^{-1} of seed at 7 days before sowing followed by treatment wise inoculation with Rhizobium and PSB @ 20 g/kg of seeds. To reduce the crop weed competition and to provide better crop growth one hand weeding was done at 21 DAS in all the treatments. The crop was sown on 19th February, 2020 and 22nd February, 2021 with the help of tyne and was harvested manually on 10th April, 2020 and 13th April, 2021 respectively. Pooled analysis of the data of both the years was done. The obtained data were subjected to the analysis of variance of Split-plot Design (Gomez and Gomez 1984).

Rooting depth and root dry weight

Three plant samples were drawn following extraction method and root depth and root dry weight was recorded from middle plant at 20 days interval till harvest. Root dry weight from collected samples at harvest was also recorded and reported as root dry weight per plant.

Number and weight of nodule per plant

The number of effective nodules and their fresh weight from the uprooted plant were recorded at two days interval and at harvest and average was worked out to get the nodule number and its fresh weight per plant.

Nutrient uptake

Total uptake of a particular nutrient was calculated by adding the uptake in main as well as by-product, which was obtained by multiplying these contents with corresponding yield value.

Soil testing

The soil samples were analysed for available Nitrogen by Alkaline KMnO4 method (Subbiah and Asija, 1956), available phosphorous by Bray's-1 'P' method (Jackson, 1973) and available potassium by Ammonium acetate extraction by flame photometer (Jackson, 1973).

Plant analysis

Using a mixture of nitric, perchloric and sulfuric acids in the proportions of 8: 1: 1 (v/v), respectively, the plant material was digested. (Chapman and Pratt, 1962). A Buechi 320-N2-distillation unit was used to distil the dry plant material in order to evaluate the nitrogen (N) content using the boric acid modification reported by Ma and Zuazage (1942). phosphorus was measured photometrically using the molybdate vanadate method (Jackson, 1973).

Seed yield

After eliminating the border rows from the either sides, the net plot was harvested, dried and threshed. The seeds were cleaned and weighed. The clean seeds were again dried to get moisture content of 8% before storing. Net plot yield was multiplied by hectare to get the per hectare yield.

RESULTS AND DISCUSSION

Root length, root dry weight and shoot

Root ratio

The root growth of mungbean (*var*. Nayagarh Local and *var*. PDM-139) was summarized in Table 2 under different land configuration methods and varying nutrient management practices. Land configuration suitably affected the root rowth and it was found that the root length and the shoot:root ratio were found to be insignificant with respect to land configuration, variety and nutrient management whereas the root dry weight was significantly affected by the treatments at harvest (Table 2). The highest root length and shoot:root ratio was found in raised bed method with PDM 139 (13.1 cm) and (6.83) respectively, whereas the lowest root length was found in flat bed with Nayagarh Local variety (10.5 cm) and (5.70) respectively. The significantly highest root dry weight was reported from raised bed with PDM 139 (1.52 g) and the lowest one was found in the flat bed with Nayagarh Local treatment (1.02 g). Similar results were reported by Sridhar *et al*., (2021) and Dhimmar, (2003). Higher root length and more root dry weight in raised bed method was attributed to free growing conditions owing to more loose and porous state than in flat bed method where the soil is more compact. Among the nutrient management treatments, the maximum root length (12.04 cm), root dry weight (1.47 g) and shoot:root ratio (6.88) was obtained from the F6 treatment combination out of which the root dry weight was significantly highest. The minimum root length (11.33), root dry weight (0.89) and shoot: root ratio (5.23) was obtained from F1 treatment combination. The interaction effect between the various treatments was expressed in Table 3 and 4 for the root dry weight and shoot: root ratio respectively.

Nodule number, nodule fresh weight

From Table 5. it was observed that, the maximum number of nodules (15.48) and the highest nodule fresh weight (25.50 mg) was reported from the treatment where the improved variety PDM 139 was grown in raised bed method of land configuration. This may attributed to the fact that in the raised bed method, the soil was loose and the conditions

Table 1: Treatment details and denotations.

Treatment details	Treatment denotations
Main plot	
Flat bed with Nayagarh local	M1V1
Flat bed with PDM-139	M1V2
Raised bed with Nayagarh local	M2V1
Raised bed with PDM-139	M2V2
Sub plot	
Farmer's Practice (100 kg DAP ha^{-1} + need based plant protection)	F1
F1+seed inoculation with Rhizobium + PSB soil application	F2
F2+lime @ 5q ha^{-1}, F4 = F2 + NPK as RDF *i.e.* 20-40-20 kg NP$_2$O$_5$-K$_2$O ha^{-1} (no flat application of DAP)	F3
F2+NPK as RDF *i.e.* 20-40-20 kg NP$_2$O$_5$-K$_2$O ha^{-1} (no flat application of DAP)	F4
F2+Soil test based NPK application, 25-40-25 kg N-P$_2$O$_5$-K$_2$O ha^{-1}	F5
F2+STCR based NPK application	F6

Table 2: Effect of land configuration and nutrient management on root length, root dry weight, shoot:root ratio at harvest (Pooled).

Treatments	Root length (cm)	Root dry weight (g)	Shoot:Root ratio
Land configuration and variety			
Flat bed with Nayagarh Local	10.5	1.02	5.70
Flat bed with PDM 139	12.1	1.35	6.59
Raised Bed with Nayagarh Local	11.2	1.16	6.09
Raised bed with PDM 139	13.1	1.52	6.83
LSD (0.05)	-	0.10	-
Nutrient management			
F1: Farmer's Practice(100 kg DAP ha^{-1} + need based plant protection)	11.33	0.89	5.23
F2: F1+ seed inoculation withRhizobium + PSB soil application	11.42	1.05	5.71
F3: F2 + lime @ 5q ha^{-1}	11.61	1.29	6.22
F4: F2 + NPK as RDF *i.e.* 20-40-20 kg N-P$_2$O$_5$-K$_2$O ha^{-1} (no flatapplication of DAP)	11.94	1.35	6.54
F5: F2 + soil test based NPK application *i.e.* 25-40-25 kgN-P$_2$O$_5$-K$_2$O ha^{-1}	12.04	1.47	6.88
F6: F2 + STCR based NPK application	12.16	1.53	7.24
LSD (0.05)	NS	0.11	NS

favoured better root growth and nodule development. Among the nutrient management practices, F6 treatment combination gave significantly higher number of nodules (16.61) which was at par with F5 treatment and the maximum nodule dry weight (25.50 mg), followed by F5 treatment. Co-inoculation with *Rhizobium* and PSB gave better root growth and nodule characteristics (Qureshi *et al*., 2011). Reclamation with lime too provide better soil pH for the nodule growth (Agba *et al*., 2019). Due to better nutrient availability in the STCR treatment, the nodule growth was superior as compared to the other treatments. This was corroborated by the study of Raghav *et al*., (2019). The

Table 3: Effect of land configuration, variety and nutrient management on root dry weight (g/plant) at harvest (Two way Table).

Land configuration and variety	Nutrient management practices						Mean
	F1	F2	F3	F4	F5	F6	
M1V1	0.77	0.61	1.14	1.17	1.20	1.24	1.02
M1V2	0.76	1.15	1.36	1.45	1.64	1.75	1.35
M2V1	0.86	1.05	1.19	1.21	1.28	1.35	1.16
M2V2	1.16	1.39	1.47	1.55	1.75	1.80	1.52
Mean	0.89	1.05	1.29	1.35	1.47	1.53	1.26
		SE (m)±		**CD (0.05)**		**CV**	
Main plot (MV)		0.02		0.10		9.69	
Sub plot (F)		0.03		0.11		10.61	
Interaction							
1. Fixed main plot		0.07		0.22			
2. Fixed sub plot		0.07		0.21			

Table 4: Effect of land configuration, variety and nutrient management on shoot: root ratio at harvest (Two way Table).

Land configuration and variety	Nutrient management practices						Mean
	F1	F2	F3	F4	F5	F6	
M1V1	4.60	5.17	5.78	6.02	6.25	6.39	5.70
M1V2	5.31	5.95	6.46	6.80	7.19	7.80	6.59
M2V1	5.11	5.45	5.99	6.31	6.70	6.99	6.09
M2V2	5.88	6.26	6.67	7.01	7.38	7.77	6.83
Mean	5.23	5.71	6.22	6.54	6.88	7.24	6.30
		SE (m)±		**CD (0.05)**		**CV**	
Main plot (MV)		0.02		NS			
Sub plot (F)		0.04		NS			
Interaction							
1. Fixed main plot		0.07					
2. Fixed sub plot		0.21					

Table 5: Effect of land configuration and nutrient management on number of nodules (no./plant), nodules fresh weight (mg) at harvest (Pooled).

Treatments	Nodule number	Nodule fresh weight (mg)
Land configuration and variety		
Flat bed with Nayagarh local	13.76	21.12
Flat bed with PDM 139	15.05	24.14
Raised bed with Nayagarh local	14.86	23.22
Raised bed with PDM 139	15.48	25.50
LSD (0.05)	NS	0.25
Nutrient management		
F1: Farmer's practice(100 kg DAP ha^{-1} + need based plant protection)	13.03	22.90
F2: F1+ seed inoculation with Rhizobium + PSB soil application	13.00	22.45
F3: F2 + lime @ 5q ha^{-1}	14.33	23.24
F4: F2 + NPK as RDF *i.e.* 20-40-20 kg N-P_2O_5-K_2O ha^{-1} (no flatapplication of DAP)	15.41	24.38
F5: F2 + soil test based NPK application *i.e.* 25-40-25 kg N-P_2O_5-K_2O ha^{-1}	16.37	24.50
F6: F2 + STCR based NPK application	16.61	25.50
LSD (0.05)	1.64	0.36

interaction effect between the various treatments was expressed in Table 6.

Nutrient uptake

The grain, straw and total nutrient uptakes (N, P and K) of both the cultivars (Nayagarh Local and PDM 139) was summarized in Table 7. It was observed that under the flat bed method of land configuration, the improved variety of summer mung, PDM 139 exhibited the maximum nutrient uptake of grain (N: 17.54 kg/ha, P: 1.88 kg/ha and K: 8.06 kg/ha), straw (N: 5.77 kg/ha, P: 0.95 kg/ha and K: 6.63 kg/ha) and total uptake (N: 23.31 kg/ha, P: 2.83 kg/ha and K: 14.69 kg/ha) respectively. Similar findings were reported by Mondal and Sengupta, 2019 and Patel *et al*., 2022. Among the Nutrient management treatments, F6 reported the highest grain, straw and total nutrient uptake (N, P and K). Application of lime reclaimed the already acidic soil to a near neutral pH, thus enabling better uptake of the nutrients. Phosphorous upon application get fixed with the inorganic soil phosphates of Ca, Fe and Al via production of siderophores, solubilizes *etc*. Hence application of Phosphorous Solubilizing Bacteria (PSB) solubilizes the inorganic soil phosphates into available forms thus increasing the uptake of the respective treatments. These findings were in line with the works of Basavaraja *et al*., 2019.

Yield

The seed yield of summer mung was significantly affected by the nutrient management. The F6 treatment significantly produced higher seed yield (455.69 kg ha^{-1}) over the other treatments (Fig 1). Besides, the STCR based nutrient management translocated more photosynthetic products to seeds, thereby helped to realize more yield. STCR approach showed encouraging results in more than 80% of the experiments conducted under different STCR centres (Rao and Srivastava, 2000).

Table 6: Effect of land configuration, variety and nutrient management on nodules fresh weight (mg) at harvest (Two way Table).

Land configuration and variety	Nutrient management practices						Mean
	F1	F2	F3	F4	F5	F6	
M1V1	18.80	20.10	20.20	21.80	21.50	24.30	21.12
M1V2	21.70	22.50	23.77	25.00	25.90	26.00	24.14
M2V1	19.80	22.70	23.80	24.00	24.30	24.70	23.22
M2V2	23.30	24.50	25.20	26.70	26.30	27.00	25.50
Mean	2.90	22.45	23.24	24.38	24.50	25.50	23.49
		SE(m)±		**CD (0.05)**			**CV**
Main plot (MV)		0.07		0.25		1.30	
Sub plot (F)		0.12		0.36		1.73	
Interaction							
1. Fixed main plot		0.23		0.67			
2. Fixed sub plot		0.23		0.64			

Table 7: Nutrient uptake (N, P and K) in grain and straw as influenced by different land configuration and nutrient management practices (Pooled).

Treatments	Nutrient uptake (kg/ha)								
	Grain			Straw			Total		
	N	P	K	N	P	K	N	P	K
Land configuration and variety									
Flat bed with Nayagarh local	11.97	1.21	5.77	3.93	0.55	4.72	15.90	1.76	10.49
Flat bed with PDM 139	17.54	1.88	8.06	5.77	0.95	6.63	23.31	2.83	14.69
Raised bed with Nayagarh local	11.08	1.17	5.21	3.61	0.56	4.25	14.69	1.73	9.46
Raised bed with PDM 139	14.65	1.65	7.01	4.66	0.83	5.48	19.31	2.48	12.49
Nutrient management									
F1: Farmer's Practice(100 kg DAP ha-1 + need based plant protection)	11.07	1.14	5.22	3.65	0.54	4.25	14.72	1.68	9.47
F2: F1+ seed inoculation withRhizobium + PSB soil application	13.48	1.43	6.32	4.37	0.69	5.14	17.85	2.12	11.46
F3: F2 + lime @ 5q ha-1	14.42	1.54	6.68	4.64	0.74	5.47	19.06	2.28	12.15
F4: F2 + NPK as RDF *i.e.* 20-40-20 kg $N-P_2O_5-K_2O$ ha^{-1} (no flatapplication of DAP)	14.96	1.63	7.01	4.93	0.81	5.76	19.89	2.44	12.77
F5: F2 + soil test based NPK application *i.e.* 25-40-25 kg $N-P_2O_5-K_2O$ ha^{-1}	13.50	1.46	6.24	4.37	0.73	5.15	17.87	2.19	11.39
F6: F2 + STCR based NPK application	15.43	1.66	7.59	5.01	0.84	5.84	20.44	2.50	13.43

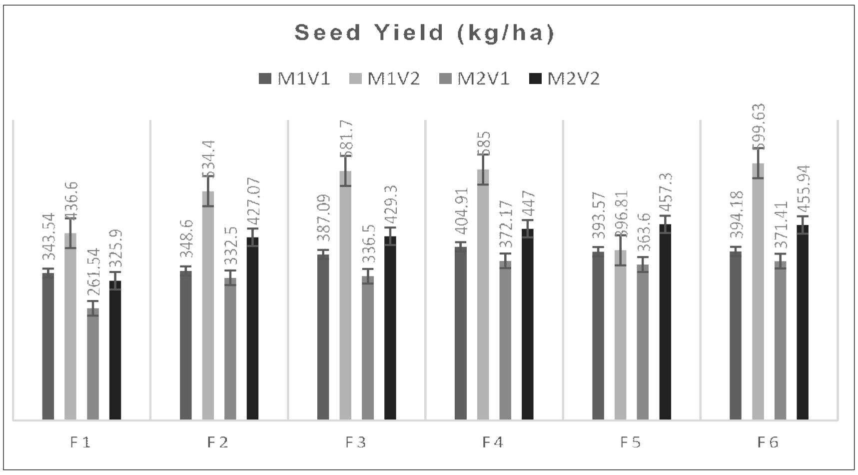

Fig 1: Seed yield of summer mung as influenced by land configuration and nutrient management.

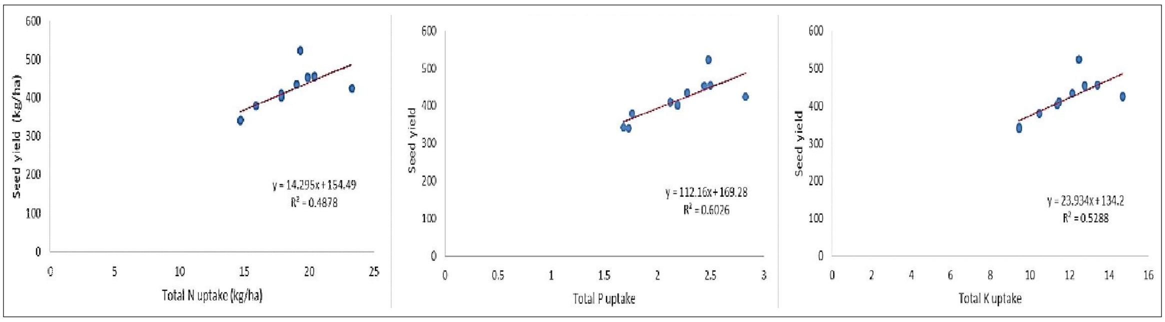

Fig 2: Linear Correlations between grain yield and total N (a), P (b) and K (c) uptake in summer mung in the experiment.

Nutrient uptake vs grain yield

The linear correlation between grain yield and nutrient uptake was displayed in Fig 2. It was found that the total uptakes of N, P and K were positively correlated with the grain yield both the varieties under the different treatment combinations ($p<0.001$). There was strong positive correlation between the total P uptake and grain yield (R^2= 0.6026) (Fig 2b.), followed by total K uptake and grain yield (R^2= 0.5288) (Fig 2c.), followed by total N uptake and grain yield (R^2= 0.4878) (Fig 2a.). This in line with the works of Singh *et al*., 2021, Santhi *et al*., 2011, Mahajan *et al*., 2013 and Ahmed *et al*., 2015. Among the treatments the application of Phosphorous solubilising bacteria (PSB) resulted in a higher yield and more Phosphorous uptake.

CONCLUSION

Thus, from the study we can conclude that, raised bed method with the PDM-139 cultivar and STCR treatment resulted in the highest pooled root length, root dry weight shoot-to-root ratio and yield. There was also a positive correlation between grain yield and respective N, P2O5, and K2O uptakes. Thus the modified raised bed method assures better growth of the green gram crop and the local variety can be replaced with the improved variety PDM 139. Moreover, the STCR strategy proves to be an efficient option for the nutrient management over the other treatments in East and South-eastern coastal plain of Odisha.

Conflict of interest: None.

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