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RESEARCH ARTICLE

STUDY ON THE EFFECT OF ROW SPACING AND NPK ON PERFORMANCE OF MUNGBEAN (*VIGNA RADIATA*) IN SUNDARBAZAR LAMJUNG

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ABSTRACT

Mungbean *(Vigna radiata)* has gained increasing significance as a crucial grain legume in Nepal's tropical and sub-tropical regions due to its short growth cycle and soil fertility enhancement properties. This research was conducted at Agronomy farm of Lamjung campus, to assess how mungbean performs under varying row spacing and Npk fertilizer levels. The study employed two-factorial Randomized Complete Block Design with three row spacing levels (20 cm, 25 cm, and 30 cm) and three NPK fertilizer doses (10:10:10, 20:20:20, and 30:30:30 kg NPK/ha) as treatments. The investigation explored phenological and yield attributing parameters. Interestingly, the outcomes showed that row spacing had negligible impact on root growth attributes, including root length and nodule formation. However, root nodule number increased with higher NPK fertilizer levels, particularly notable with the application of (30:30:30) kg NPK/ha, resulting in the highest nodules per plant (140.40), while the lowest nodules (91.35) were observed with (10:10:10) kg NPK/ha. Vital traits like plant height, branch and leaf counts, pod set, pod length, and seed weight were unresponsive to both NPK doses and row spacing levels. In contrast, grain yield exhibited a substantial increase with NPK fertilizer application, with the highest yield (1263.55 kg/ha) achieved with (30:30:30) kg NPK/ha and the lowest (929.27 kg/ha) with (10:10:10) kg NPK/ha. Therefore, this study shows strong correlations, especially between root nodules and grain yield, emphasized key links. NPK doses impacted vital root nodules for nitrogen fixation and suggests dense planting of Pratikshya mung beans with increased NPK fertilizer.

KEYWORDS

Mungbean, NPK fertilizer, Row spacing, Root nodule, Yield

1. INTRODUCTION

Mung is the colloquial name for the green gram, often known as the mungbean *(Vigna radiata L.)* which belongs to the family Leguminosae. It is a significant pulse crop with excellent nutritional value and affordable protein. It has a decent amount of protein (24.21%), vitamin A (80 units), carbohydrates (69.30%), and calories (high). By utilizing root nodules to fix atmospheric nitrogen, it restores soil fertility (Jamro et al., 2018). The mungbean has a reasonable amount of minerals and vitamins as well as high-grade vegetable proteins. Due to its pleasant flavor, simple digestion, improved palatability, and reasonable market price, mungbean may be farmers' first option (Kabir and Sarkar, 2008). Planting density has a significant impact on mungbean seed production and yield components. It is typically grown by farmers without maintaining right sowing technique is one of the crucial biotic variables that determines the right plant population, which enhances the performance and productivity of plants in the field (Birhanu et al., 2018).

The correct amount of nitrogen applied at the time of sowing causes rapid growth of the plant's leaf area, increases the duration of the leaf area (LAD), and causes an increase in the plant's overall assimilation rate after flowering, all of which help to increase seed yield (Jamro et al., 2018). Phosphorus is essential for carbohydrate production and transport, root development, crop maturation, and disease pathogen resistance. This increases mungbean yield and improve its quality (Farrukh et al., 2003). Phosphorus has been recognized as one of the most limiting nutrient factors in crop productivity in tropical soils, causing a reduction in total vegetative growth, secondary branches, leaf development, and, ultimately, yields of mung bean on all types of soil (Farrukh et al., 2003). Potassium plays a crucial part in boosting plant vigor, lengthening straw, and aiding in the swift healing of damages brought on by insects, hail, and wind. Lack of potassium also reduces yield since plants with little seeds grow slowly and produce fewer fruits and vegetables (Jamro et al., 2018). To increase the yields of legumes, fertilizers with the right balance of nitrogen, phosphorus, and potassium must be used (Kumar, 2022).Due to competition for light, space, water, and nutrients, adequate spacing can lower mungbean output up to 40% (Birhanu et al., 2018).The ideal spacing encourages plants to grow in both their aerial and subsurface sections by effectively utilizing nutrients and solar radiation, which increases grain output. Also, physiological activities are directly impacted by plant spacing due to intra-specific competition (Suvra Roy et al., 2014).

Mungbean is an important food legume that is widely grown in many countries, including Nepal. Despite its importance, the productivity of mungbean in Sundarbazar, Lamjung is often limited by various factors such as row spacing and NPK fertilizer. Row spacing is an important factor in mungbean production as it affects the distribution of light, air, and water to the plants, which in turn affects the growth, yield, and quality of the crops. However, there is limited information available on the optimal row spacing for mungbean production in Sundarbazar, Lamjung, Nepal. NPK fertilization is another important factor that affects the growth, yield, and quality of mungbean. Nitrogen, phosphorus, and potassium are essential nutrients for plant growth and play a crucial role in the development of roots, stems, leaves, and flowers. However, the use of

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excessive NPK fertilizers can cause environmental degradation and increase production costs.

In view of the above factors, there is a need to evaluate the effect of row spacing and NPK fertilization on the performance of mungbean in Sundarbazar, Lamjung, Nepal. Thus, this study aims to determine the optimal row spacing and NPK fertilization for mungbean production in this region.

2. MATERIALS AND METHODS MATERIAL

2.1 Experimental Location

A field experiment was conducted at the agronomy farm of Lamjung Campus in Sundarbazar, Lamjung in the year 2023. The farm lies in the western mid-hills of Nepal (700 masl) with coordinates 28°07′37.0′′N 84°25′00.5′′ to evaluate to evaluate the effect of row spacing and NPK fertilization on the performance of mungbean in Sundarbazar, Lamjung, Nepal.

2.2 Crop Details

Crop: Mungbean

Scientific Name: Vigna radiata var. mungo

Family: Leguminosae

Variety: Pratikshya

2.3 Design of Experiment

A randomized complete block design (RCBD) was used for the study. The experimental units were mungbean plots, and the treatments were different combinations of row spacing and Npk fertilization levels. The design of the experiment was two factor factorial Randomized Complete Block Design (RCBD) with 9 treatments and 3 replications.

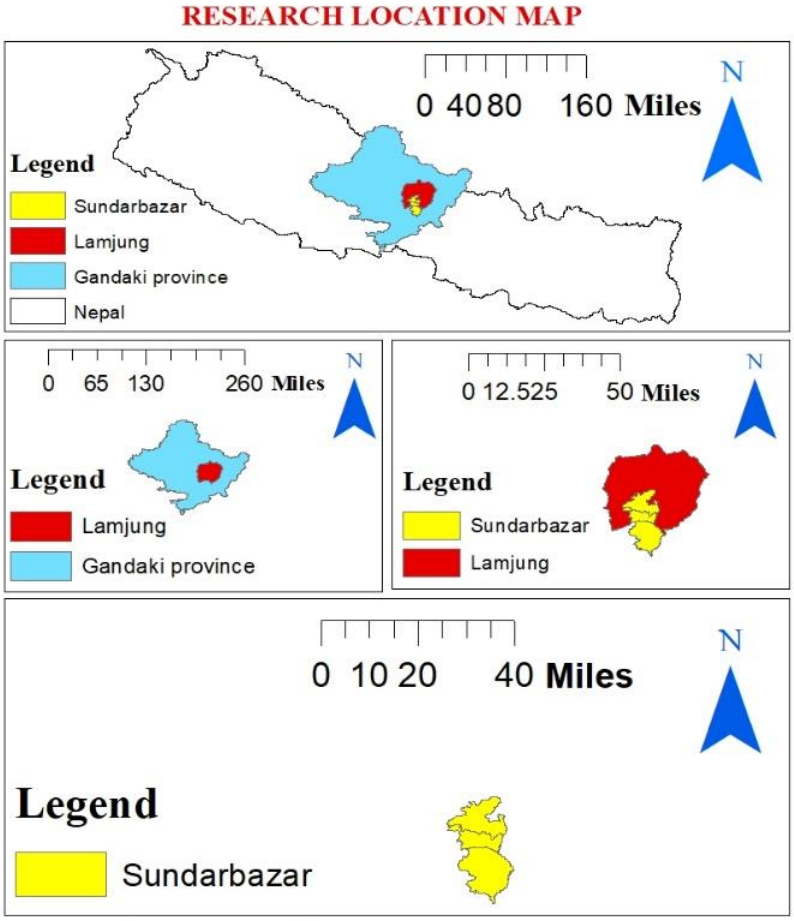

Figure 1: Location of the Study Area

2.4 Treatments

Factor A: Row Spacing

3 levels of row spacing:

S1- 20 cm

S2- 25 cm

S3- 30 cm

Factor B: Doses of Npk Fertilizer

3 levels of NPK Fertilizer

F1- 10:10:10 Npk

F2- 20:20:20 Npk

F3- 30: 30: 30 Npk

2.4.1 Treatments Combination

S.N.	Treatment	Combinations
1	T1	S1(20 cm) + F1 (10:10:10 NPK)
2	T2	S1(20 cm) + F2 (20:20:20 NPK)
3	T3	S1(20 cm) + F3(30: 30:30 NPK)
4	T4	S2(25 cm) + F1 (10:10:10 NPK)
5	T5	S2 (25 cm) + F2 (20:20:20 NPK)
6	T6	S2 (25 cm) + F3 (30: 30:30 NPK)
7	T7	S3 (30 cm) + F1 (10:10:10 NPK)
8	T8	S3 (30 cm) + F2 (20:20:20 NPK)
9	T9	S3 (30 cm) + F3 (30: 30:30 NPK)

2.5 Field Layout

Plot size: 1.5m x 1m

Treatment: 9

Replication: 3

Total No of Plots: 27

2.6 Experimental Procedure

2.6.1 Dry Land Preparation and Treatment Arrangement

Tillage was done twice to ensure the soil was well-prepared with a good tilth and recommended dose of FYM i.e. 70kg was mixed according to the area of field. Then the field was divided into blocks and individual plots using statistical methods for factorial experiment on 10th March 2023. Different inter-row spacing levels of 20, 25 and 30 cm were maintained with consistent intra-row spacing. The appropriate level of NPK was calculated, mixed properly, and placed 5 cm away from each row in every plot in split doses (50% NPK and 25% in 30 DAS and remaining 25% in 45 DAS).

2.6.2 Seed Sowing

The seeds were hydro soaked by immersing them in water for a span of 12 hours. Following this hydration phase, the seeds were air-dried in a shaded environment and subsequently employed for sowing. Planting was done with a placement of two seeds per spot.

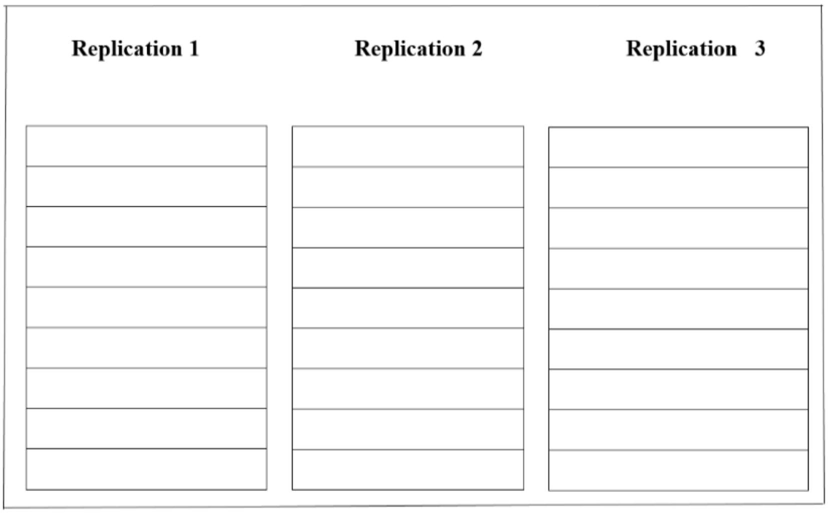

Figure 2: Layout of the experimental design of the Research field.

2.6.3 Crop Duration

30th March 2023 - 1st July 2023

2.6.4 Intercultural Operation

Different weeds like broad, narrow and sedges were seen in the field. So weeding was done manually on 30 DAS and 45 DAS to manage weed in the field. Hoeing was followed after each manual weeding.

2.6.5 Irrigation

Irrigation was done at the initial stage for germination of seeds (0-15 DAS), early vegetative stage (15-35 DAS), flowering stage (35-45 DAS), and Pod setting stage (45-55 DAS) at the interval of two to three days.

2.6.6. Sowing Methods and Depth

Line sowing was carried out while maintaining a 2-3 cm depth. Any spaces left between the seeds were also filled in later.

2.6.7 Application of Pesticide

The field was infected with insects, especially cutworms affecting the roots. The insecticide Cartap hydrochloride was sprayed at 28 DAS and G-Sunami @ 5 ml per litre of water was sprayed at 30 DAS.

2.6.8 Harvesting and Threshing

To prevent shattering loss, harvesting was done multiple times after the maturity of pods. The first harvesting was done by hand-picking on 13th June 2023 and the last final harvest was done on 25th June 2023 by cutting the whole plant with the help of a sickle. The yield was recorded according to the plots and harvest from 5 tagged plants were kept separately in the lab for data collection. The harvested seeds were threshed manually by keeping pods in sacks and beating with sticks and sundried.

2.7 Data collection

2.7.1 Sampling and tagging of plants

Tagging was done by selecting 5 plants from inner rows of each plot using red ribbons to visualize the sampled plants easily. The required data were taken from sampled plants.

2.7.2 Growth Parameters

2.7.2.1 Plant Height

Plant height of sampled plants was measured using a scale on the 30th, 45th, and 60th DAS by lengthening the plant to the tip.

2.7.2.2 Number of Branches Per Plant

The number of branches of five sampled plants was counted on the 30th, 45th, and 60th DAS.

2.7.2.3 Number of Leaves Per Plant

The total number of leaves of sampled plants was counted on the 30th, 45th and 60th DAS.

2.7.2.4 Number of Root Nodule Per Plant

The number of root nodules of five sampled plants was counted by cleaning the roots with fresh water at the time of harvest.

2.7.2.5 Length of Root

The length of primary root of five sampled plants was measured by using scale at the time of harvest.

2.7.2.6 Fresh Weight of Root

The fresh weight of the root of five sampled plants was measured by using electrical weighing balance.

2.7.2.7 Dry Weight of Root

The roots of the sampled plant were dried in an oven, and dry weight measurements were made using an electrical weighing scale.

2.7.2.8 Fresh Weight of Shoot

The fresh weight of shoot of five sampled plants was measured by using electrical weighing balance.

2.7.2.9 Dry Weight of Shoot

The shoot portion of sampled plant were oven dried and dry weight was taken by using electrical weighing balance.

2.7.3 Yield Parameters

2.7.3.1 Number of Pods Per Plant

The total number of pods from five sampled plants was counted and averaged.

2.7.3.2 Number of seeds per pods

Ten pods were chosen from the total number of harvested pods from the sampled plants, and the number of seeds was tallied and averaged.

2.7.3.3 Length of Pod

Ten pods were chosen from the total number of harvested pods from the sampled plants, and the length of each pod was tallied and averaged.

2.7.3.4 Seed Weight

One hundred seeds were randomly selected from each plot's harvest sample and weighted in an electrical balance.

2.7.3.5 Grain Yield

The weight of seeds threshed from the pods of five sampled plants was sundried, weighed on an electrical balance, and translated to kilogram per hectare.

2.8 Data Analysis

The recorded data was first entered and managed on MS-excel and analyzed using R-studio. Duncan's Multiple Range Test (DMRT) was employed to find out any significant differences between the mean values at a 5% level of significance.

3. Results and Discussions

3.1 Growth Parameters

3.1.1 Plant Height

Height data was collected at three different intervals, namely 30 days after sowing (DAS), 45 DAS, and 60 DAS. The results showed that the plant height was not significantly affected by varying row spacing. The tallest plant heights at 30 DAS, 45 DAS, and 60 DAS were observed in distinct row spacing conditions: S1 spacing had the maximum height (16.71 cm) at 30 DAS, S3 spacing had the highest height (29.94 cm) at 45 DAS, and S1 spacing displayed the greatest height (54.89 cm) at 60 DAS. Conversely, the shortest plant heights at these intervals were observed under different row spacing conditions: S3 spacing had the minimum height (15.95 cm) at 30 DAS, S1 spacing had the lowest height (29.16 cm) at 45 DAS, and S2 spacing exhibited the smallest height (52.99 cm) at 60 DAS. Non-significant downfall of plant height with rise of row spacing from 30 t0 50 cm (Tehulie et al., 2021).

Similarly, the application of Npk fertilizers did not significantly influence plant height on different days. The maximum plant heights at 30 DAS, 45 DAS, and 60 DAS were associated with different fertilizer doses: F_1 dose had the tallest height (17.20 cm) at 30 DAS, F_2 dose showed the greatest height (30.58 cm) at 45 DAS, and F_3 dose presented the highest height (55.07 cm) at 60 DAS. On the contrary, the lowest plant heights at this time interaction inked to different fertilizer doses: F_3 dose had the minimum height (15.95 cm) at 30 DAS, F_3 dose exhibited the shortest height (28.74 cm) at 45 DAS, and F_1 dose displayed the smallest height (53.36 cm) at 60 DAS.

Table 1: Effect of row spacing and Npk fertilizer on plant height of mungbean.

Treatments		**Plant Height**	
Row Spacing (cm)	PH30	PH45	PH60
S_1 (20)	16.7^a	29.16^a	54.89^a
S_2 (25)	16.46^a	29.36^a	52.99^a
S_3 (30)	15.95^a	29.94^a	54.24^a
NPK Fertilizer (kg/ha)			
F_1(10: 10: 10)	17.20^a	29.13^{ab}	53.36^a
F_2 (20: 20: 20)	16.25^{ab}	30.58^a	53.70^a
F_3 (30: 30:30)	15.66^b	28.74^b	55.07^a
F- test	NS	NS	NS
LSD $_{(0.05)}$	1.10	1.75	4.28
SEm (±)	0.13	0.20	0.48
CV%	6.87	5.96	7.93
Grand Mean	16.37	29.49	54.04

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level. PH30: Plant height at 30 days, PH45: Plant height at 45 days, PH60: Plant height at 60 days.

3.1.2 Number of Branch Per Plant

Table 2 below presents the data, indicating that number of branches emerged on the mung bean plant at 30 days after sowing (DAS). However, on subsequent days (45 DAS and 60 DAS), altering row spacing (25 cm and 30 cm) did not result in any observable changes in the number of branches per plant. Similarly, the count of branches per plant remained unchanged despite varying doses of NPK fertilizer, with no notable distinctions, both at 45 days and 60 days after sowing. In contrast, the number of branches plant-1 increases with plant spacing (Taufiq and Kristiono, 2016). As opposed to that, the use of various fertilizer dosages makes branches number to be changed (Sarker et al., 2023).

Table 2: Effect of row spacing and Npk fertilizer on branch number of mungbean.

Treatments		**Number of Branch**	
Row Spacing (cm)	NB30	NB45	NB60
S_1 (20)	-	3.30^a	6.89^a
S_2 (25)	-	3.24^a	6.68^a
S_3 (30)	-	3.02^a	6.31^a
NPK Fertilizer	-		
F_1 (10: 10: 10)	-	3.07^a	7.27^a
F_2 (20: 20: 20)	-	3.40^a	7.20^a
F_3 (20: 30:30)	-	3.10^a	7.07^a
F- test	-	NS	Ns
LSD $_{(0.05)}$	-	0.071	0.15
SEm (±)	-	0.008	0.02
CV%	-	14.14	18.62
Grand Mean	-	3.19	6.62

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level. NB30: Branch number at 30 days, NB45: Branch number at 45 days, NB60: Branch number at 60 days.

3.1.3 Number of Leaf Per Plant

The presented bar graph demonstrates that altering row spacing (20 cm, 25 cm, and 30 cm) did not result in any significant changes in the number of leaves per plant. In contrast, researchers found that Interaction effect of spacing and different nutrient management showed significant variation on number of leaves per plant at different days after sowing (Sarker et al., 2023). Similarly, the quantity of leaves per plant remained uninfluenced by varying levels of Npk fertilizer, revealing no significant distinctions. Similar result were found that; there was no effect of interaction between applied doses of fertilizer and mungbean cultivars on the number of leaves (Achakzai et al., 2012).

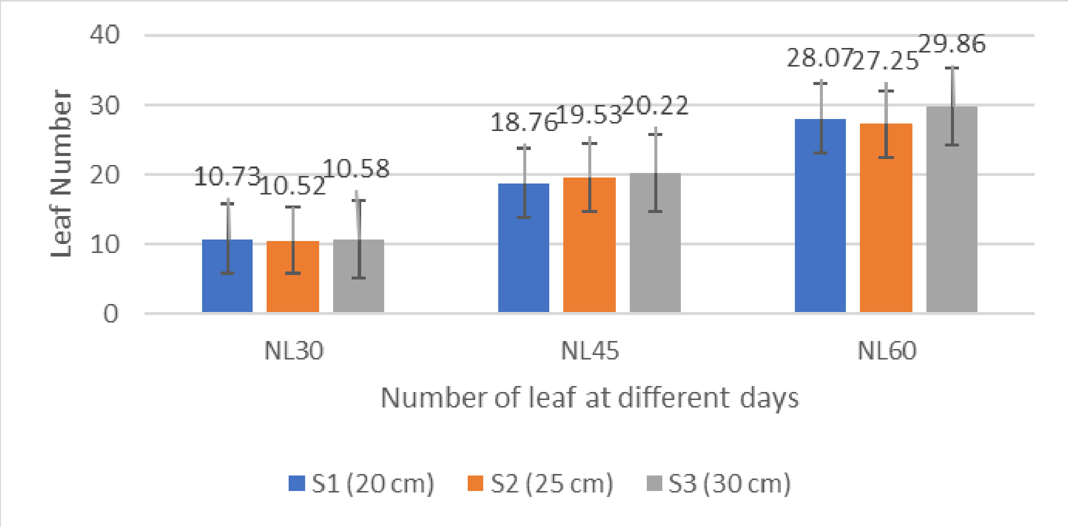

Figure 3: Bar graph showing the effect of row spacing on Leaf number of mungbean.

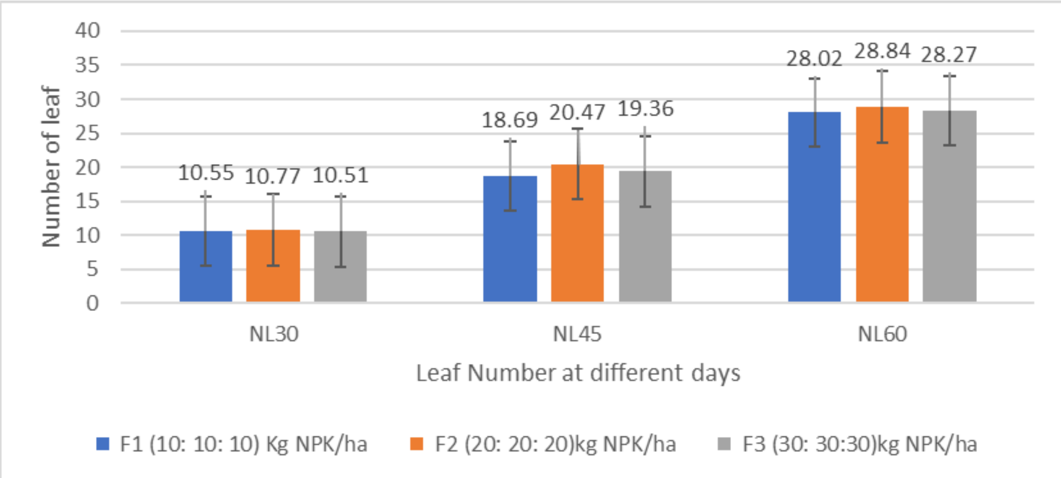

Figure 4: Bar graph showing the effect of Npk Fertilizer on Leaf number of mungbean.

3.1.4 Root Length

The variation in row spacing did not lead to a statistically significant impact on root length. However, among the different row spacing configurations, the most extended root length (22.15 cm) was observed in the narrower spacing of 20 cm, while the shortest length (20.94 cm) occurred in the 25 cm row spacing.

Similarly, the application of Npk fertilizer did not yield a statistically significant influence on root length. Nevertheless, the plots treated with (10:10:10) kg Npk/ha exhibited the longest root length (22.44 cm), while the shortest Root length (20.68 cm) was observed in plots treated with (20:20:20) kg Npk/ha.

3.1.5 Number of Root Nodules Per Plant

Variations in row spacing did not lead to a statistically significant difference in the total number of root nodules per plant. The highest count of nodules (119.24) was observed in plots with wider row spacing (30 cm), while the lowest count (107.20) occurred in plots with 25 cm row spacing. Researchers study revealed that row spacing does not affect the number of root nodules in mungbean (Rasul et al., 2012).

Conversely, the total count of root nodules per plant was profoundly affected by Npk fertilizer application, showing a highly significant influence ($P < 0.05$). Applying (30:30:30) Kg Npk/ha resulted in the greatest number of nodules per plant (140.40), whereas using (10:10:10) Kg Npk/ha yielded the fewest nodules per plant (91.35). Phosphorous nutrient promotes healthy growth fibrous lateral roots that increases the root nodules numbers (Rahman et al., 2008).

3.1.6 Fresh and Dry Weight of Root

The spacing between rows did not show a notable influence on the weight of fresh roots. However, there was a slight tendency for root weight to increase as the row spacing was widened, although this trend was not statistically significant. Among the row spacing options, the widest spacing of 30 cm produced the heaviest fresh roots (10.30 gm), while the narrower 20 cm spacing resulted in lighter roots (8.20 gm).

Likewise, applying different amounts of Npk fertilizer did not lead to a significant change in the fresh root weight. The most substantial weight (9.54 gm) was achieved with 10:10:10 Kg NPK/ha, while the least weight (8.82 gm) was recorded with 20:20:20 kg Npk/ha. In contrast, dry root weight was significantly affecting by the Npk fertilizer (Islam, 2021) .

For the dry weight of roots, neither row spacing nor Npk fertilizer doses showed a significant effect. This indicates that variations in row spacing and Npk fertilizer levels, as tested in the experiment, did not cause any notable changes in the dry weight of roots.

3.1.7 Fresh and Dry Weight of Shoot

The spacing between rows made a significant difference in the weight of fresh shoots, displaying a noticeable influence. As the gap between rows widened, there was an evident tendency for shoot weight to go up. Among the various row spacing options, the widest gap of 30 cm yielded the heaviest fresh shoots (65.79 gm), while the narrower 20 cm spacing resulted in lighter shoots (53.45 gm).

Conversely, adjusting the quantities of NPK fertilizer applied did not yield a significant change in the weight of fresh roots. The highest weight (61.43 gm) was achieved using 20:20:20 Kg Npk/ha, while the lowest weight (53.42 gm) was recorded with 10:10:10 kg Npk/ha. These findings are similar to the findings of a researchers that conclude the dry shoot weight adversely affected by the different doses of Npk fertilizers (Islam, 2021).

Concerning the dry weight of shoots, neither the spacing between rows nor the Npk fertilizer levels had a significant impact. This implies that the variations tested in row spacing and Npk fertilizer amounts did not trigger noteworthy alterations in the dry weight of shoots, mirroring the findings seen in the case of root dry weight.

Table 3: Effect of row spacing and Npk fertilizer on the root length and root nodules number of mungbean.

Treatments	Root length (cm)	Number of Root Nodules per plant
Row Spacing (cm)		
S_1 (20)	22.15[a]	109.80[a]
S_2 (25)	20.94[a]	107.20[a]
S_3 (30) F-test	21.93[a] NS	119.24[a] NS
NPK Fertilizer (kg/ha)		
F_1 (10: 10: 10)	22.44[a]	91.35[b]
F_2 (20: 20: 20)	20.68[a]	104.49[b]
F_3 (30: 30:30)	21.91[a]	140.40[a]
F- test	NS	***
LSD $_{(0.05)}$	2.23	13.33
SEm (±)	0.25	1.48
CV%	10.30	11.90
Grand Mean	21.67	112.08

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level.

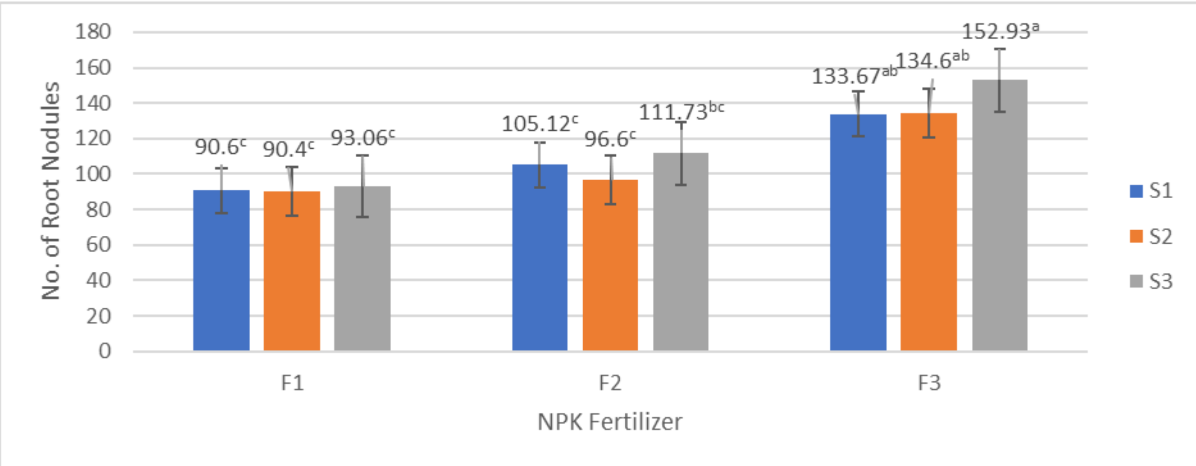

Figure 5: Bar graph showing the effect of row spacing and Npk fertilizer on the root nodule of mungbean.

Table 4: Effect of row spacing and Npk fertilizer on the fresh and dry weight of mungbean's roots and shoots.

Treatments	Root fresh weight (gm)	Shoot fresh weight (gm)	Root dry weight (gm)	Shoot dry weight (gm)
Row Spacing (cm)				
S_1 (20)	8.20[a]	51.35[b]	2.83[a]	13.57[a]
S_2 (25)	8.96[ab]	58.18[ab]	2.99[a]	14.35[a]
S_3 (30)	10.30[a]	65.79[a]	3.57[a]	15.75[a]
F- test	NS	*	NS	NS
NPK Fertilizer (kg/ha)				
F_1 (10: 10: 10)	9.54[a]	53.45[a]	3.21[a]	13.16[a]
F2 (20: 20: 20)	8.82[a]	61.43[a]	2.99[a]	15.55[a]
F_3 (30: 30:30)	9.12[a]	59.87[a]	3.19[a]	14.99[a]
F- test	NS	NS	NS	NS
LSD $_{(0.05)}$	1.78	0.08	0.89	0.10
SEm (±)	0.20	0.10	0.10	0.01
CV%	19.45	4.47	28.54	8.74
Grand Mean	9.16	58.15	3.13	14.53

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level.

3.2 Yield Parameters

3.2.1 Number of Pods Per Plant

The number of pods on each plant did not change significantly, regardless of adjustments in row spacing, variations in Npk fertilizer quantities, and their combined influences, as highlighted by the study. Likewise, Rasul et al. (2012)and Singh et al. (2012) reached the same consensus, observing that altering row spacing did not influence the count of pods on each plant. However, Gurjar & Vithalbhai Patel (2018) reported an increase in the number of pods per plant with wider row spacing. This could be due to the fact that changes in row spacing and Npk fertilizer doses did not notably impact other parts of the mungbean plant, such as height and branches, which might consequently affect the pod count.

3.2.2 Pods Length

The Length of the pod remained unchanged by variations in row spacing, doses of Npk fertilizer, and their combined effects, as per the study's outcomes. Additionally, Birhanu et al. (2018) arrived at a similar conclusion, noting the absence of any impact from planting density on pod length. Similarly, Ihsanullah et al. (2002) also found non-significant result on the pod length by the effect of row spacing.

3.2.3 Number of Seeds Per Pod

The study showed that changing the distance between rows didn't lead to important differences, but interestingly, the highest number of seeds per pod was obtained with a 30 cm row spacing, followed by 20 cm, and the lowest with 25 cm. Singh et al. (2012) research study found no differences in the number of seeds per pod as a result of different row spacing.

The impact of varying the doses of Npk fertilizer also did not show significant differences either, and the most seeds were obtained using (10:10:10) Npk at Kg/ha. In conclusion, the study suggests that altering row spacing and trying different Npk doses does not impact or alter the number of seeds per pod. In contrast, Debnath et al. (2022) found that data regarding number of pod plant-1 was affected by different levels of Npk.

Table 5: Effect of row spacing and Npk fertilizer on pod number, pod length and seeds per pod of mungbean.

Treatments	Number of pods per plant	Pod length (cm)	Number of seeds per pod
Row Spacing (cm)			
S_1 (20)	28.51^{ab}	8.62^{a}	12.64^{a}
S2 (25)	23.97^{b}	8.72^{a}	12.49^{a}
S_3 (30)	30.44^{a}	8.97^{a}	12.99^{a}
NPK Fertilizer (kg/ha)			
F_1(10: 10: 10)	25.34^{a}	8.89^{a}	12.86^{a}
F_2 (20: 20: 20)	28.36^{a}	8.74^{a}	12.63^{a}
F_3 (30: 30:30)	29.22^{a}	8.68^{a}	12.63^{a}
F- test	NS	NS	NS
$LSD_{(0.05)}$	5.45	0.49	0.48
SEm (±)	0.61	0.05	0.053
CV%	19.72	5.55	3.76
Grand Mean	27.64	8.77	12.71

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level.

3.2.4 Grain Yield

There was no significant change in grain yield with increasing row spacing. This indicates that altering the distances between rows (20cm, 25cm, and 30cm) did not result in any variations in mungbean grain yield. In contrast, Gella & Adare (2021) study found that significantly ($p < 0.05$) maximum grain yield (2346.67 kg ha^{-1}) was attained at an inter-row spacing of 25 × 10 cm.

On the other hand, a notable difference ($p<0.05$) in grain yield emerged due to the application of different Npk fertilizer doses in the study. The highest grain yield (1263.55 kg/ha) was recorded with a fertilizer dose of (30:30:30) kg NPK/ha, followed by 1060.56 kg/ha with (20:20:20) kg Npk/ha. The lowest grain yield (929.27 kg/ha) was observed with (10:10:10) kg Npk/ha. One of the studies Debnath et al. (2022) shows that Variations in Npk levels had a significant impact on seed yield. The 16:20:24 kg N: P: K ha^{-1} treatment produced the highest seed yield (1.52 t ha^{-1}), whereas the control treatment produced the lowest yield (1.22 t ha^{-1}).

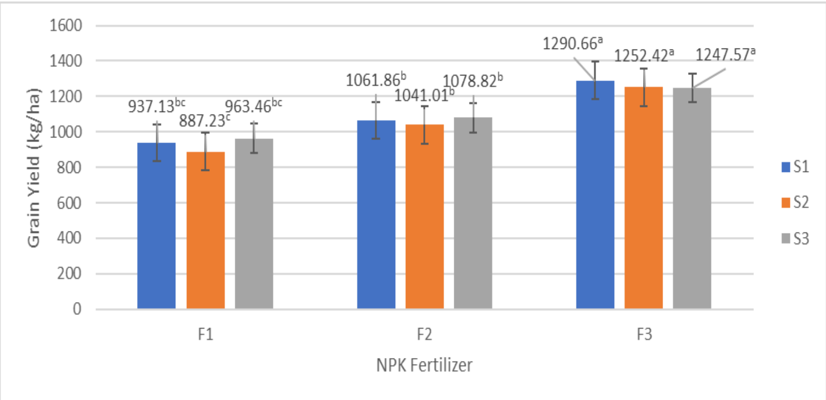

Figure 6: Bar graph showing the effect of row spacing and Npk fertilizer on the grain yield of mungbean.

3.2.5 Seed Weight

The study found that altering the distance between rows, experimenting with different Npk doses, and their combinations did not lead to any noticeable differences in the weight of the grain. This aligns with Tehulie et al. (2021) findings, which also indicated that changing row spacing did not result in any important changes in the weight of a hundred seeds. This lack of significant change in seed weight could be mainly due to the fact that seed weight is primarily determined by the genetic makeup of the plant variety, which might overshadow the effects of changes in how the plants are grown.

3.3 Interaction Effect of Growth And Yield Parameters

The results obtained from the Analysis of Variance (ANOVA) revealed that the variations in the growth and yield parameters of mungbean were not found to have a significant influence. When considering the means of different treatment conditions, it was observed that for certain parameters, there were no substantial differences that could be attributed to the treatments.

Table 6: Effect of row spacing and Npk fertilizer on grain yield and 100 seed weight of mungbean.		
Treatments	**Grain yield (kg/ha)**	**100 Seed weight (gm)**
Row Spacing (cm)		
S_1 (20)	1096.55[a]	3.60[a]
S_2 (25)	1060.22[a]	3.58[a]
S_3 (30)	1096.62[a]	3.59[a]
F- test	NS	NS
NPK Fertilizer (kg/ha)		
F_1 (10: 10: 10)	929.27[c]	3.59[a]
F_2 (20: 20: 20)	1060.56[b]	3.59[a]
F_3 (30: 30:30)	1263.55[a]	3.59[a]
F- test	***	NS
LSD $_{(0.05)}$	86.61	0.03
SEm (±)	9.63	0.003
CV%	7.99	0.79
Grand Mean	1084.46	3.59

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level.

Table 7: Effect of row spacing and Npk on the growth and yield parameters of mungbean.			
Treatments	**Plant Height (cm)**	**Root Nodule number**	**Grain Yield (kg/ha)**
$S1F_1$	32.02	90.60	937.1267
$S1F_2$	33.66	105.13	1061.86
S_1F_3	34.83	133.67	1290.66
S_2F_1	32.59	90.40	887.23
S_2F_2	33.85	96.60	1041.01
S_2F_3	32.61	134.60	1252.42
S_3F_1	34.13	93.07	963.46
S_3F_2	33.97	111.73	1078.82
S_3F_3	32.04	152.93	1247.57
F- test	NS	NS	NS
CV%	5.85	11.90	7.99
Grand Mean	33.30	112.08	1084.46

As per the DMRT approach, means within a column sharing the same letter(s) are statistically alike, while means with distinct letter(s) across columns differ significantly at a 0.05 probability level.

3.4 Correlation Analysis Relation Between Growth and Yield Parameters

The heat map of the correlation matrix illustrates Pearson correlation coefficients for growth and yield parameters of mungbean. Positive correlations are denoted in blue, negative in red. The scale ranges from -1 to 1: -1 signifies a complete negative linear relationship, 1 indicates a perfect positive linear relationship, and 0 represents no connection between variables. The studied parameters include average plant height, branch and leaf numbers, root length, pod number, pod length, root nodule number, seeds per pod, 100 seed weight, and grain yield.

The data in Figure 7 reveals both the significant and non-significant patterns. Notably, the number of root nodules displays a robust and positive relationship with grain yield (r = 0.90***). Likewise, the average leaf count exhibits a moderate and positive connection with pod quantity (r = 0.62**). Similarly, pod length, root length, pod number, and average plant height all exhibit moderate positive correlations with seeds per pod count (r = 0.52**), number of seeds per pod (r = 0.46**), 100 seed weight (0.44**), and pod length (r = 0.42**) respectively. In contrast, other parameter relationships demonstrate weak positive correlations, as well as minor negative associations and insignificance. A highly significant and positive correlation between grain yield and the number of pods plant^{-1} (0.744) and grain yield plant-1 (0.888) (Achakzai and Panizai, 2007). While other entries failed to establish any meaningful connections with plant grain yields.

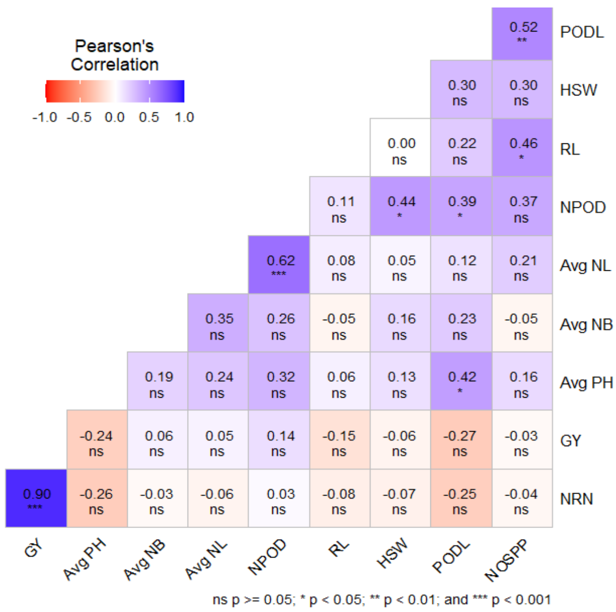

Figure 7: Pearson's correlation heat map between growth and yield traits of mungbean by the effect of row spacing and Npk fertilizer.

4. Conclusions

In summary, this research highlights that changing row spacing (20cm, 25cm, 30cm) did not significantly affect mungbean grain yield. However, varying NPK fertilizer doses did impact grain yield, with the highest (30:30:30) kg NPK/ha resulting in 1263.55 kg/ha, and the lowest (10:10:10) kg NPK/ha yielding 929.27 kg/ha. The study found a subtle influence of row spacing on plant height, with trends that were observable but statistically insignificant. Similarly, different NPK fertilizer doses had minimal effects on plant height across various time periods, suggesting a moderate response to fertilization within the tested NPK range. Additionally, the investigation demonstrated how branch and leaf counts remained stable in response to various row spacing's and Npk doses. This indicates a negligible impact of these elements on the overall vegetative growth of mungbean plants.

While Npk doses had little to no effect on root length, some variations in root length were seen when row spacing was changed. Npk fertilization, however, was found to have a significant impact on the total number of root nodules per plant, which are essential for nitrogen fixation. Minimal changes were seen in pod characteristics like pod count and length when row spacing and Npk doses were changed, indicating that these traits were less sensitive to the tested variables.

Surprisingly, despite resistance to changes in row spacing and Npk doses, the weight of individual seeds and overall grain yield frequently failed to reach statistical significance. This emphasizes how genetic factors have a decisive impact on seed weight and grain yield. Intricate relationships between the various parameters were revealed by correlations, particularly a significant positive relationship between root nodule count and grain yield. This emphasizes how important nitrogen fixation is for increasing yield potential.

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