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Impact of dates of sowing and plant geometry on growth and nutrient uptake of ricebean (*Vigna umbellata* L.)

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Abstract
On-site investigations were performed during *kharif* season of 2022 at the College of Agriculture, Kalaburagi, to examine the influence of sowing schedules and planting configurations on the growth and nutrient assimilation of ricebean. The study was designed using a split-plot layout with three replications. The trial involved two treatment factors: sowing time assigned to the main plots with four intervals—second fortnight of July, first fortnight of August, second fortnight of August, and first fortnight of September—and spacing arrangements in the subplots with three planting geometries—30 cm × 10 cm, 45 cm × 10 cm, and 60 cm × 10 cm. The findings revealed that ricebean seeded during the first fortnight of August exhibited significantly greater growth attributes *viz.*, tallness of crop, quantity of branches and leaves per plant, leaf area, total biomass gain (67.91 cm, 30.08, 64.14, 51.64 cm^2 $plant^{-1}$, 27.75 g $plant^{-1}$, respectively) and nutrient uptake of nitrogen (34.53 kg ha^{-1}), phosphorous (22.7 kg ha^{-1}) and potassium (85.31 kg ha^{-1}) compared to other sowing periods.
Among different plant geometry, 30 cm x 10 cm documented significantly higher plant height (64.05 cm), but count of clusters and leaves, leaf area, total biomass production was notably higher (27.01, 59.86, 45.16 cm^2 $plant^{-1}$, 23.92 g $plant^{-1}$ respectively) with 60 cm x 10 cm. Besides higher nutrient acquisition of nitrogen (30.54 kg ha^{-1}), phosphorous (18.20 kg ha^{-1}) and potassium (76.48 kg ha^{-1}). In addition, it showed similar performance to the 45 cm × 10 cm spacing.

Keywords: Dates of sowing, spacing, growth, nutrient uptake, plant geometry and Ricebean

Introduction
Ricebean is a native of South-East Asia, belonging to the family Leguminaceae, subfamily Faboideae. It is believed to originate from the wild type of *Vigna umbellata* var. *gracilis* with which it is cross-fertilized and which is distributed from Southern China to Burma and India. Ricebean (*Vigna umbellata*) is a short-duration legume predominantly cultivated as an annual crop. It exhibits notable morphological variability, showing erect, semi-erect, or twining growth habits. Plant height normally ranges from 30 to 100 cm, although it may extend up to 2 m under favourable conditions. These species develop a well-established root system characterized by a prominent tap root that penetrates to depths of 100-150 cm. Stems are branched and covered with very fine trichomes. The foliage consists of trifoliate leaves bearing entire leaflets which measure 6-9 cm in length. Inflorescences are axillary racemes, 5-10 cm in length, with bright yellow flowers. The pods are cylindrical, measuring 7.5-12.5 cm long, and contain 6-10 oblong seeds, each approximately 6-8 mm in size with a distinct concave hilum. Seed coat colour is highly variable, ranging from greenish-yellow to black, with intermediate shades such as yellow and brown; among these, yellow-brown seeds are considered the most nutritious. Ricebean can be cultivated across a wide spectrum of soil types, including shallow, low-fertility and degraded soils, indicating its adaptability to marginal environments. Optimal spatial arrangement and density of crops, which fundamentally influences crop productivity. Proper spatial arrangement of plants plays a pivotal role in maximizing light interception, which is necessary for efficient photosynthesis. This enhances the absorption of nutrients and overall growth of the plant. Inadequate or improper spacing can lead to excessive intra-specific competition for light, water and nutrients, ultimately resulting in lower yields. Therefore, adopting appropriate plant spacing is fundamental to achieving optimal resource use efficiency and maximizing crop yield potential.

Materials and Methods

The trial took place at College of Agriculture, Kalaburagi situated in the N-E Dry Zone of Karnataka (Zone 2), UAS, Raichur (Karnataka). The trial site is found at 17°34′ North latitude and 76°79′ East longitude, with an elevation of 478 meters above mean sea level. The soil at the study location is classified as black clay, characteristic of Vertisols, known for their high moisture retention capacity and fine texture, low in organic carbon (0.49%) and available nitrogen (245 kg ha^{-1}), medium in available phosphorus (52.2 kg ha^{-1}) and high in potassium (389 kg ha^{-1}). The ricebean variety KBR-1 was used for experimentation. The crop was established using the dibbling method, with plant spacing maintained according to the respective treatment specifications. A basal application of the recommended fertilizer dose of 20 kg N and 40 kg P_2O_5 per hectare was carried out using urea and diammonium phosphate (DAP), placed at a depth of 5 cm within the furrows during sowing. Additionally, well-decomposed farmyard manure (FYM) was incorporated into the soil at a rate of 6 tonnes per hectare, 15 days prior to sowing, to enhance soil fertility and organic matter content.

Growth parameter analysis

The methodology adopted for recording various growth parameters is outlined as follows:

Plant height (cm)

Plant height was observed at 30 and 60 DAS and at harvest using a standard metric scale. Measurements were taken from the soil surface to the apex of the uppermost fully expanded leaf on each plant, representing the vertical growth attained during the respective growth stages of five randomly selected tagged plants in each treatment and the average was determined and stated in centimetres.

Number of Clusters/plants

The number of clusters originating from the main stem was recorded by enumerating them on five arbitrarily selected and tagged plants in each treatment at 30, 60 DAS and at harvest and the mean was worked out and expressed as the number of clusters per plant.

Number of leaves/plants

The leaves emerging from the primary and secondary clusters were counted on five tagged plants in each treatment at 30, 60 and at harvest and the mean was calculated and presented as the number of leaves per plant.

Leaf Area (cm^2/plant)

Leaf Area was noted by following disc method. Ten leaf discs of known dimensions were collected using a cork borer from randomly selected leaves of five representative plants per treatment. Both the excised discs and the corresponding remaining leaf blades were subjected to oven-drying at 70°C until their stabilized weight was achieved. Leaf area was then estimated at consecutive growth phase of crop using the appropriate calculation formula derived by using the dry weights.

$$\text{Leaf Area} = \frac{\text{Wa} \times \text{A}}{\text{Wb}}$$

Where,
LA = Leaf area (cm^2 $plant^{-1}$)
Wa = Oven dry weight of all leaves
Wb = Oven dry weight of 10 discs (g)
A = Area of the 10 discs (cm^2), A = πr^2

Leaf area index

Leaf Area Index (LAI) was worked out by dividing the total leaf area per plant to the land covered by the plant as per the expression derived by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{/plant)}}{\text{Spacing (cm}^2\text{/plant)}}$$

Plant analysis

At the time of harvest, the collected plant samples were initially dried in air and then dried in a hot air oven at 65^0C. The dried samples were ground to a fine powder using a grinder fitted with stainless steel blades and subsequently stored in polyethylene bags for further analytical procedures (Jackson, 1973).

Total Nitrogen

Total nitrogen content in plant samples was determined using the Kjeldahl method, as described by Jackson (1973). In this procedure, 0.5 g of finely ground plant material was digested with concentrated sulfuric acid (H_2SO_4) in the presence of a digestion catalyst mixture consisting of potassium sulphate (K_2SO_4), copper sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$), and selenium in a ratio of 100:20:1. The resulting digest was neutralized under alkaline conditions, and the ammonia (NH_3) released was captured in a boric acid solution containing a mixed indicator. The trapped ammonia was then quantified by titration with standard sulfuric acid (H_2SO_4).

Digestion of plant samples with di-acid mixture

For the estimation of phosphorus and potassium, 0.5 g of finely ground plant material was initially pre-digested with 5 ml of concentrated nitric acid (HNO_3). This was followed by complete digestion using a di-acid mixture of nitric acid and perchloric acid (HNO_3: $HClO_4$) in a 10:4 ratio. The final digest was diluted to a volume of 100 ml with distilled water and used for subsequent analysis of phosphorus and potassium, following the approach described by Jackson (1973).

Total Phosphorus

Total Phosphorus content of ricebean plant samples was assessed by taking a known quantity of digested samples using the Vanadomolybdenum-phosphoric yellow colour technique as described by Jackson (1973).

Total Potassium

The complete potassium content of the digested di-acid plant samples were estimated by incinerating the digested and diluted sample to a modulated flame photometer under appropriate measuring circumstances as defined by Jackson (1973).

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{\% Nutrient content x Total biomass yield (kg ha}^{-1}\text{)}}{100}$$

Results and Discussion

Impact of dates of sowing and plant geometry on growth parameters of ricebean

Plant height: Date of sowing was significantly influenced the plant height. Sowing during first fortnight of August recorded higher vertical growth of plant (67.91 cm). This Variations in tallness of plant across different sowing dates can be credited to the accessibility of favourable temperature and solar radiation during critical stages of crop growth. These conditions likely enhanced vegetative development through improved accumulation of photosynthates in plant tissues. Similar observations were reported by Mukherjee *et al.* (2004) in ricebean. Among the spacing treatments, a planting geometry of 30 cm × 10 cm resulted in significantly greater plant height (64.05 cm) compared to 60 cm × 10 cm. However, it was statistically comparable to the 45 cm × 10 cm spacing, which recorded a plant height of 62.39 cm. This may be caused by light competition among crops that are spaced closer together. Because there was little light, it also promotes self-thinning of branches, which promoted vertical growth as opposed to horizontal development. Consequently vertical growth of crop was more evenly distributed at closer spacing. Similar results were also reported by Rudragouda in rice bean.

Number of clusters: Date of sowing significantly influenced the quantity of clusters plant^{-1}. Sowing during first fortnight of August recorded the higher number of branches per plant^{-1}(30.08). This is mainly because of reduced competition for nutrients and favourable environmental factors. These results are consistent with the observations reported by Sheoran and Rana (2007). The crop sown at a spacing of 60 cm × 10 cm recorded a remarkably higher number of clusters per plant (27.01) compared to the 30 cm × 10 cm spacing. However, it was statistically on par with the 45 cm × 10 cm spacing, which recorded 25.49 clusters per plant. This could be a result of inter and intra-row plant competition for sunlight among the plants at closer spacing. Wider spacing might be attributed to less competition for resources, subsequently improving available soil moisture of the plant, nutrients and light for better development of these characters. Analogous outcome were reported by Rudragouda in ricebean.

Number of leaves: Date of sowing significantly influenced the number of leaves plant^{-1}. Sowing during first fortnight of August noted the more number of leaves plant^{-1} (64.14). This is due to that crop might have experienced excellent weather in terms of temperature, rainfall, and other climatic factors that contributed to crop growth at various stages and leaf count plant^{-1} were produced more. This is consistent with what has been found by Kumar and Singh (1998), Mohapatra (1998) in ricebean and Kurubetta (2006) in cowpea. Crop **s**own with 60 cm x 10 cm observed susbstantial rise in leaf count plant^{-1} (59.86) as contrast to 30 cm x 10 cm and it was on par with 45 cm x 10 cm spacing (57.61). Increased spacing resulted in more leaves being produced because of their favourable effects on the triggering of leaf primordia and the encouragement of more carbohydrates being produced by influencing cell enlargement. Since leaves are essential for photosynthesis and produce the bulk of biomass and leaf count will also influence yield. This is mainly because of reduced competition for nutrients and cardinal environmental factors. These results corroborate the findings of Khanda and Mishra.

Leaf area: Date of sowing significantly influenced on leaf area. Sowing during the first fortnight of August recorded a higher leaf area (51.64 cm^2 plant^{-1}). Maintaining adequate functional leaf coverage is an significant factor for higher rate of photosynthesis and this becomes even more important particularly after flowering when sink size is already determined and photosynthates produced in leaves start accumulating in sink. As a result, ambient meteorological conditions of crop sown on first fortnight of August produced higher leaf area, which was due to the effective use of growth resources. Similar outcomes were recorded by Singh and Singh (2000) for french bean. Crop **s**own with 60 cm x 10 cm showed significantly higher leaf area (45.16 cm^2 plant^{-1}) and it was on par with the 45 cm x 10 cm (43.96 cm^2 plant^{-1}). Wider spacing might be less attributed to competition for resources, subsequently improving available soil moisture, nutrients and light for better development of these characters. Similar results were reported by Darwesh (2012) for cowpea.

Leaf area index: Date of sowing significantly influenced leaf area index. Sowing during the first fortnight of August recorded a higher leaf area index (0.122). This is because of availability of adequate conditions increases the effectiveness of mineral nutrients applied to crop, thus increasing the foliage of the plant and also efficient use of resources over a longer period, boosting leaf area index. Similar findings were recorded by Singh and Singh (2000) for french bean. Crop **s**own with 30 cm x 10 cm resulted in remarkably higher leaf area index (0.118) compared to 60 cm x 10 cm and it was found to be on par with 45 cm x 10 cm (0.098) and presented in Table 1. Rise in LAI with an increase in planting density was due intensive planting. A comparable and analogous report from Sai Babu and Garg (1988) for mungbean.

Effect of sowing dates and plant geometry on Nutrient uptake (cf. Fig. 1)

Sowing of crop during first fortnight of August shown increased absorption of nitrogen (34.53 kg ha^{-1}), phosphorus (22.7 kg ha^{-1}) and potassium (85.31 kg ha^{-1}). This could be a result of number of ions present in the surrounding medium has an impact on how quickly nutrients are absorbed. The crop sown during the first fortnight of August recorded a higher capacity for biomass production, which, combined with a longer vegetative phase and continuous availability of favourable conditions for improved nutrient uptake by the crop, results in elevated biomass yield, which in turn increases yield. Parallel results were reported by Kumar and Kumavat for mungbean.

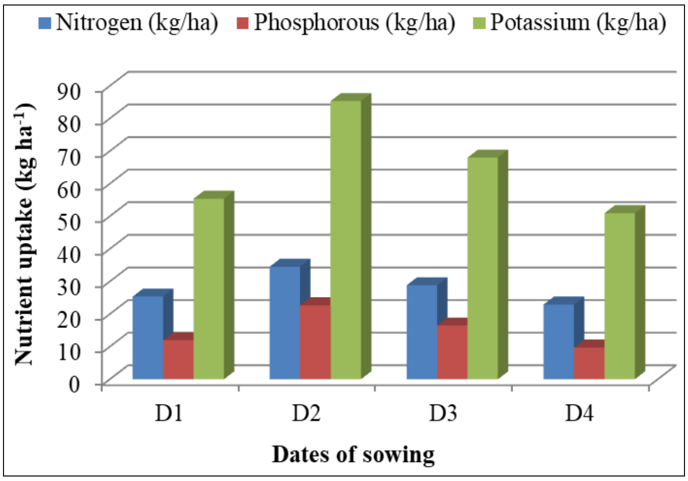
Crop sown with a configuration of 30 cm x 10 cm recorded higher the nitrogen uptake (30.54 kg ha^{-1}), phosphorous (18.20 kg ha^{-1}) and potassium (76.48 kg ha^{-1}) compared to 60 cm x 10 cm and it was found on par with 45 cm x 10 cm (29.24 kg ha^{-1}, 17.39 kg ha^{-1} and 74.21 kg ha^{-1}, N, P & K respectively). In comparison to the wider row spacing, the absorption of nitrogen, phosphate and potassium was higher under closer row spacing**.** Because there is a greater plant density, producing more biomass and dry matter. Hence, there was a greater uptake of nutrients under closer spacing, indicating a greater requirement for nutrients. Similar results were also reported by Patel in cowpea.

Interaction effect: The interaction between the dates of sowing and plant geometry on growth parameters and nutrient uptake was found to non-significant.

Table 1: Effect of sowing dates and plant geometry on growth parameters of ricebean

Treatment	Plant height (cm)	Number of clusters $plant^{-1}$	Number of leaves $plant^{-1}$	Leaf area (cm^2 $plant^{-1}$)	Leaf area index
Main plot: Date of sowing (D)					
D_1 - Second fortnight of July	59.32	24.18	53.46	36.53	0.084
D_2 - First fortnight of August	67.91	30.08	64.14	51.64	0.122
D_3 - Second fortnight of August	61.41	25.47	57.02	43.91	0.104
D_4 - First fortnight of September	55.08	22.57	46.23	33.94	0.076
S. Em.±	1.54	0.64	1.76	1.84	0.005
C.D. at 5%	5.33	2.23	6.08	6.37	0.016
Sub plot: Spacing (S)					
S_1 - 30 cm x 10 cm	64.05	24.21	48.17	35.40	0.118
S_2 - 45 cm x 10 cm	62.39	25.49	57.61	43.96	0.098
S_3 - 60 cm x 10 cm	56.34	27.01	59.86	45.16	0.073
S. Em. ±	0.88	0.67	1.05	0.81	0.003
C.D. at 5%	2.65	1.99	3.14	2.44	0.010
Interaction: D×S					
D_1S_1	62.13	23.27	47.41	28.80	0.096
D_1S_2	61.03	24.30	55.26	39.39	0.088
D_1S_3	54.80	24.96	57.71	41.41	0.069
D_2S_1	71.18	28.83	55.59	46.28	0.154
D_2S_2	69.44	29.50	67.13	54.05	0.120
D_2S_3	63.10	31.92	69.68	54.60	0.091
D_3S_1	63.86	24.60	51.56	40.11	0.134
D_3S_2	62.68	25.53	58.83	45.15	0.100
D_3S_3	57.68	26.27	60.68	46.48	0.077
D_4S_1	59.03	20.16	38.10	26.43	0.088
D_4S_2	56.41	22.65	49.23	37.25	0.083
D_4S_3	49.78	24.90	51.36	38.13	0.056
S. Em.±	3.20	1.74	3.69	3.58	0.010
C.D. at 5%	NS	NS	NS	NS	NS

Note: NS - Non-significant



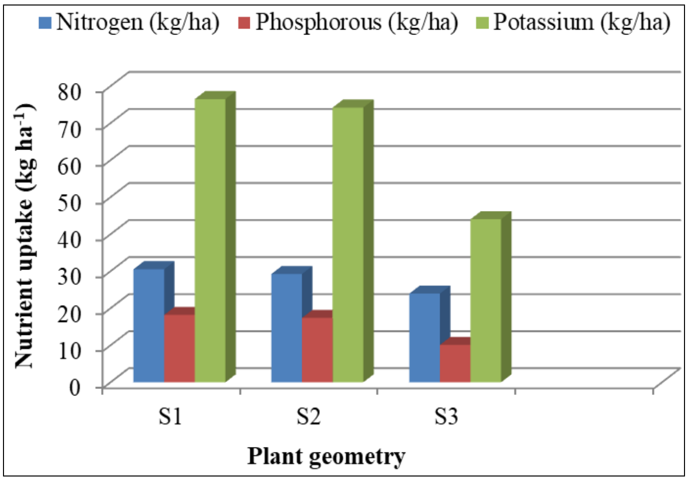


Fig 1: Uptake of total nitrogen, phosphorous and potassium by ricebean as influenced by different dates of sowing and plant geometry

Conclusion

The experimental findings showed that there were marked variations in the productivity of ricebean owing to the sowing dates and plant geometry. Based on the present investigation, it can be concluded that ricebean sown during first fortnight of August observed greater nutrient assimilation and attributed to growth parameters. Among plant geometry, crop sown with a configuration of 30 cm x 10 cm are attributed to growth parameters and Higher nutrient uptake.

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