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Effect of fertilizer level and spacing on seed yield and quality of babchi (*Psoralea corylifolia* L.)

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Nutrient management and maintenance of optimum number of plants per unit area are considered as important management tool for enhancing the productivity of crop plants. Therefore this experiment was conducted to identify the optimum level of NPK fertilizer and spacing required for obtaining higher seed yield with quality in underutilized medicinal plant babchi (*Psoralea corylifolia* L.). The evaluation was conducted with three different NPK fertilizers levels (80:40:30, 100:60:50 and 120:80:70 kgha^{-1}) and four different spacings (45×30, 45×45, 60×30 and 60×45 cm) in two seasons viz., kharif and rabi. Significant variations were observed in most of the observed parameters, it expressed that the fertilizer recommendation of NPK at 100:60:50 kgha^{-1}, adopting the spacing of 60×30 cm maximized the seed yield upto 2404 kg ha^{-1} with the resultant seed germination of 43%. It was 27.6% higher than 80:40:30 kg ha^{-1} NPK. The protein (18.69%) content of the seeds was also higher with these management techniques in both the seasons. Therefore the optimum fertilizer recommendation of 100:60:50 kgha^{-1} NPK and spacing of 60×30 cm could be recommended for babchi seed production.

Key words: Fertilizer level, spacing, seed yield, babchi, medicinal plant.

INTRODUCTION

Approximately 80% of the world population has their faith on natural products of plant kingdom for their secured health and prophylactic healing. Khalil et al. (2007) reported that though developing countries have their fashion to allelopathy for immediate cure, in this millennium, irrespective of developing /developed status, the global nations focus their vision on naturopathy for sustained relief without repercussion from health disorders. *Psoralea corylifolia* L. commonly called karpokkarasi or babchi is a medicinal plant belonging to the Fabaceae family. Babchi is an erect, annual herb that grows up to 160 cm under cultivation. It bears a single seeded pod which is indehiscent and the pericarp is usually found adhering to the seed. The pericarp is sticky and oily containing coumarins, of which Psoralen and Isopsoralen are therapeutically important. It is one of the main herbs in traditional Chinese herbal medicine for the treatment of skin conditions. It has been used in treating leprosy and psoriasis, eczema and hair loss. In addition, *Psoralea* is used to promote bone calcification, making it useful for treating osteoporosis and bone fractures. Besides treating psoriasis, psoralen is being investigated as a cure for several diseases including AIDS. This species has a large distribution in the South- Eastern districts of Madhya Pradesh and Uttar Pradesh. In addition, it has a wider distribution in parts of Rajasthan, Andhra Pradesh, Bihar and Gujarat and related semi-tropical grasslands in the country with the average pod productivity of 2 t ha^{-1} (Farooqi and Sreeramu, 2001).

Medicinal plants are grown well in a very broad range of ecological conditions. But, no attempt has so far been made for the extensive cultivation of many species

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except a very few, that are being exported. Hence, it is warranted to trace crop management techniques for large scale production such as suitable fertilizer level and spacing so as to get higher yield of good quality seeds. Success of any crop clinks largely towards nutrient management, as nutritional elements available in soil reflects the transfer of source to the sink (Pouryousef et al., 2007). Researchers from time immemorial expressed that nitrogen, phosphorus and potassium are essential nutrients for plant growth and development. Nitrogen is the chief constituent of protein and coenzyme it is essential for the formation of protoplasm that leads to cell division, cell enlargement and biological reproductivity of living organisms (Bakly, 1974), while phosphorus is the constituent of cellular protein and nucleic acids that activate the meristematic properties of the plants (Black, 1973). Potassium is involved in activation of enzymes which are fundamental to metabolic processes, especially the production of proteins and sugar, improves nitrogen use efficiency, and promotes the photosynthetic rate and also in maintenance of viability and vigour in storage (Ditschar and Ivanova, 2005). Crop management with balanced fertilizer application therefore, assumes greater importance in seed production as viewed by researchers. According to Ramesh et al. (1989) in medicinal plants use of N, P, K and manures resulted in better growth and yield. Sudheendra et al. (1993) reported that for the fullest exploitation of the nutrients by the crop, application of optimum fertilizer was required.

Adoption of plant geometry is another important agronomic factor that contributes to higher yield and the multifaceted seed quality (Alexalbert, 2007). Ponnuswamy and Rangasamy (1996) opined that for getting higher seed yield and quality, maintenance of adequate plant density is vital as it determines the yield per unit area. Optimum plant density is required for complete use of environmental conditions (water, air, light and soil) by the plants and also to minimize the inter or intra- specific competition (Sadeghi et al., 2009). Success in absorption of nutrients from soil depends on the spacing adopted for production. Hence, adequate supply of nutrients under correct crop spacing becomes important for obtaining higher seed yield. Therefore the quantum of macronutrients required for each and every crop has to be specified especially the seed crops as they require higher levels than commercial crops (Savithri and Srimathi, 2001). Babchi is one of the underutilized medicinal crops in India in which the studies on standardization of nutrient and spacing requirements will favour commercial production. Hence, the objective of present study was formulated to identify the optimum level of fertilizer and spacing required to obtain a higher seed yield with good quality.

MATERIALS AND METHODS

The field experiment was conducted in Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore in two seasons (Kharif, Rabi) with split plot design (spacings in main plot and fertilizers levels in sub plot) to fix optimum level of nitrogen (N), phosphorus (P), potassium (K) fertilizers and spacing required for realizing higher yield associated with good quality seeds. The trial was conducted with three different NPK fertilizers levels (80: 40: 30, 100: 60: 50 and 120: 80: 70 NPK kgha^{-1}) and four different spacings (45×30, 45×45, 60×30 and 60×45 cm) with three replications using a plot size of 3 m×3 m. For all the treatments, half dose of N (in the form of urea) and full dose of P (in the form of single super phosphate) and K (in the form of muriate of potash) were applied basally prior to sowing and another half dose of N was applied as top dressing on 45th day after sowing. Recommended cultural and plant protection measures were followed throughout the crop period (Farooqi and Sreeramu, 2001) and the following observations were recorded: Field emergence (%), plant height (cm) (distance between the ground level to the tip of the main branch of plant), biomass production plant^{-1} (g) (plants were uprooted, washed with water, air dried and then oven dried at 85±2°C for 48 h and weighed), leaf length (cm) (length between the base of petiole to tip of the leaf through mid rib region), leaf breadth (cm) (measured horizontally at the widest point of the leaf), chlorophyll content (mg g^{-1}) (Yoshida et al., 1972), number of branches plant^{-1}, number of racemes plant^{-1}, days to first (days taken for initiation of flowering from the date of sowing) and 50% flowering (days taken for flowering of 50% plants from the date of sowing), pod yield ha^{-1} (kg), seed yield ha^{-1}(kg), 100 seed weight (g), germination (%) (ISTA, 2010), seedling length (cm), vigour index (Abdual- Baki and Anderson, 1973), seed protein content (%) (Ali-Khan and Youngs, 1973) and seed oil content (%) (AOAC, 1960).

Statistical analysis

The data gathered from different observations were analysed for ‘F’ test of significance following the methods described by Panse and Sukhatme (1985). Wherever necessary, the percent values were transformed to angular (Arc-sine) values before analysis. The critical differences (CD) were calculated at 5% probability level. The data were tested for statistical significance (*). If F test is non-significant, it was indicated as NS.

RESULTS AND DISCUSSION

Effect of fertilizer levels

The evaluations made with three different fertilizer levels expressed that application of NPK at 100:60:50 kg ha^{-1} registered the maximum plant height, biomass production, leaf length, breadth, chlorophyll content, number of branches and number of racemes per plant in both the seasons at 90 days after sowing (Tables 1 to 8 and Figure 1), while the minimum values were recorded with NPK applied at 80:40:30 kgha^{-1}, the suboptimal dose. The days to first and 50% flowering were delayed by 1 and 2 days respectively, with NPK applied at 100:60:50 kgha^{-1} due to promotion of vegetative growth by the increased levels of nitrogen (Pandey et al., 1994). Vijayageetha et al. (2011) in mustard also obtained delayed flowering with increased dose of nitrogen. Application of NPK at 100:60:50 kgha^{-1} enhanced pod and seed yield in both the seasons. The increase could

Table 1. Influence of fertilizer level and spacing on plant height and chlorophyll content.

Spacing (cm) (S)	Plant height at 90 days after sowing (cm)								Chlorophyll content (mg g^{-1})							
	Kharif				Rabi				Kharif				Rabi			
	NPK kgha^{-1} (F)								NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	86.9	95.2	92.9	91.7	65.0	67.3	65.1	65.8	0.810	0.835	0.822	0.822	0.800	0.815	0.807	0.807
45x45	94.7	97.2	95.0	95.6	71.0	77.9	74.1	74.3	0.830	0.842	0.839	0.837	0.802	0.819	0.811	0.811
60x30	96.9	98.7	97.3	97.6	78.0	81.5	80.0	79.8	0.842	0.864	0.859	0.855	0.881	0.897	0.889	0.889
60x45	95.6	101.3	100.0	99.0	74.7	89.9	84.8	83.1	0.867	0.895	0.883	0.882	0.898	0.900	0.899	0.899
Mean	93.5	98.1	96.3	96.0	72.2	79.2	76.0	75.8	0.837	0.859	0.851	0.849	0.845	0.858	0.852	0.852
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.522	0.220	0.634	0.440	1.231	0.359	1.363	0.718	0.004	0.003	0.006	0.005	0.010	0.001	0.010	0.001
CD (P=0.05)	1.278	0.467	1.485	0.933	3.011	0.761	3.253	1.522	0.009	0.005	NS	NS	0.024	0.002	0.025	0.003

Table 2. Influence of fertilizer level and spacing on leaf length and breadth.

Spacing (cm) (S)	Leaf length at 90 days after sowing (cm)								Leaf breadth at 90 days after sowing (cm)							
	Kharif				Rabi				Kharif				Rabi			
	NPK kgha^{-1} (F)								NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	6.6	6.7	6.7	6.7	6.1	6.2	6.2	6.2	4.7	5.0	4.8	4.8	4.3	4.5	4.4	4.4
45x45	6.7	6.9	6.8	6.8	6.2	6.4	6.3	6.3	5.0	5.0	5.0	5.0	4.3	4.6	4.5	4.4
60x30	6.8	7.0	6.8	6.9	6.3	6.5	6.3	6.3	5.0	5.1	5.0	5.0	4.5	4.6	4.5	4.5
60x45	6.8	8.0	7.4	7.4	6.3	7.2	6.8	6.8	4.8	5.4	5.2	5.1	4.5	4.9	4.6	4.7
Mean	6.7	7.2	6.9	6.9	6.2	6.6	6.4	6.4	4.9	5.1	5.0	5.0	4.4	4.6	4.5	4.5
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.049	0.030	0.068	0.059	0.043	0.025	0.058	0.049	0.030	0.017	0.041	0.035	0.018	0.019	0.036	0.039
CD (P=0.05)	0.120	0.062	0.156	0.124	0.104	0.052	0.134	0.104	0.074	0.037	0.095	0.074	0.044	0.041	0.080	0.082

be attributed to the increase in number of branches and number of racemes per plant that increased the photosynthetic area of the plant. This could be possible due to the physiological activation of sink by the major nutrients and the increase was in line with the views of Hanumanthappa et al. (1998) in soybean and Sarika et al. (2006) in linseed. Tisdale and Nelson (1975) also expressed that the nutrients applied at optimum dose, induced the formation of protease enzymes in adequate quantities that activated the anabolic metabolism in seeds that resulted in improved seed quality. In the present study also, NPK at 100:60:50 kgha^{-1} enhanced the resultant seed quality characters like 100 seed weight, germination, seedling length, dry matter production, vigour index, protein and oil content. Plants normally have certain limitation in potential uptake and utilization of nutrients for their growth and metabolism, beyond which excess or minimum application of nutrients has no role, but

Table 3. Influence of fertilizer level and spacing on number of branches and number of racemes.

Spacing (cm) (S)	Number of branches plant^{-1} at 90 days after sowing								Number of racemes plant^{-1} at 90 days after sowing							
	Kharif				Rabi				Kharif				Rabi			
	NPK kgha^{-1} (F)								NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	7	8	8	8	9	10	10	10	75	79	77	77	91	99	95	95
45x45	9	9	9	9	9	11	10	10	90	95	93	92	98	107	104	103
60x30	10	10	10	10	11	12	11	11	98	100	99	99	113	117	115	115
60x45	10	11	10	10	11	13	12	12	98	111	100	103	114	130	123	122
Mean	9	10	9	9	10	12	11	11	90	96	92	93	104	114	109	109
	S	F	S at F	F at S	S	F	S at F	F at S	S	F	S at F	F at S	S	F	S at F	F at S
SEd	0.203	0.118	0.280	0.236	0.340	0.118	0.390	0.236	1.287	0.215	1.334	0.430	1.346	0.333	1.452	0.667
CD (P=0.05)	0.496	0.250	NS	NS	0.831	0.250	0.924	0.500	3.149	0.456	3.234	0.912	3.295	0.707	3.487	1.413

Table 4. Influence of fertilizer level and spacing on days to first and 50 per cent flowering.

Spacing (cm) (S)	Days to first flowering								Days to 50 per cent flowering							
	Kharif				Rabi				Kharif				Rabi			
	NPK kgha^{-1} (F)								NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	42	43	44	43	53	54	55	54	52	53	54	53	65	65	66	65
45x45	42	43	44	43	53	54	55	54	50	52	53	52	64	64	66	64
60x30	42	43	44	43	53	54	55	54	50	51	52	51	63	64	65	64
60x45	42	43	44	43	53	54	55	54	49	50	50	50	60	63	64	62
Mean	42	43	44	43	53	54	55	54	50	52	52	51	63	64	65	64
	S	F	S at F	F at S	S	F	S at F	F at S	S	F	S at F	F at S	S	F	S at F	F at S
SEd	0.031	0.049	0.086	0.098	0.012	0.010	0.020	0.019	0.187	0.152	0.311	0.304	0.218	0.167	0.348	0.333
CD (P=0.05)	NS	0.104	NS	NS	NS	0.020	NS	NS	0.458	0.323	0.696	0.645	0.532	0.353	0.783	0.707

which in turn decreased the growth and yield parameters (Vijayageetha, 2007). In line with this opinion, in babchi application of NPK at 120:80:70 kgha^{-1} and NPK at 80:40:30 kgha^{-1} decreased the yield and yield attributing characters. The seed yield and quality improvement by different levels of NPK irrespective of seasons could be summarized as shown in Table 9.

Effect of spacings

Among the adopted crop spacing, the wider spacing (60x45 cm) recorded maximum growth and yield parameters like plant height, biomass production, leaf length, breadth, chlorophyll content, number of branches and racemes per plant, pod and seed yield per plant (Tables 1 to 8 and Figure 2) compared to closer spacings (45×30,

Table 5. Influence of fertilizer level and spacing on pod yield and 100 seed weight.

Spacing (cm) (S)	Pod yield ha^{-1} (kg)							
	Kharif				Rabi			
	NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	1111	1597	1193	1300	1296	1782	1378	1485
45x45	1198	1881	1399	1493	1613	2257	1773	1881
60x30	1944	2723	2173	2280	2265	3005	2458	2576
60x45	1657	2216	1821	1898	1890	2420	2035	2115
Mean	1478	2104	1647	1743	1766	2366	1911	2014
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	14.252	5.373	16.736	10.745	14.888	5.185	17.128	10.371
CD (P=0.05)	34.874	11.389	39.448	22.779	36.432	10.993	40.543	21.985

Spacing (cm) (S)	100 seed weight (g)							
	Kharif				Rabi			
	NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	1.300	1.314	1.305	1.307	1.300	1.316	1.309	1.308
45x45	1.301	1.320	1.309	1.310	1.301	1.325	1.315	1.314
60x30	1.310	1.450	1.320	1.360	1.319	1.493	1.325	1.379
60x45	1.312	1.499	1.318	1.376	1.320	1.515	1.327	1.387
Mean	1.306	1.396	1.313	1.338	1.310	1.412	1.319	1.347
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.0011	0.0011	0.0021	0.0022	0.0014	0.0013	0.0025	0.0025
CD (P=0.05)	0.0028	0.0024	0.0047	0.0047	0.0035	0.0027	0.0056	0.0054

Table 6. Influence of fertilizer level and spacing on germination and seedling length (root+shoot).

Spacing (cm) (S)	Germination (%)							
	Kharif				Rabi			
	NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	41(39.82)	42(40.40)	42(40.40)	42(40.40)	42(40.40)	44(41.56)	44(41.56)	43(40.98)
45x45	41(39.82)	42(40.40)	42(40.40)	42(40.40)	42(40.40)	44(41.56)	44(41.56)	43(40.98)
60x30	41(39.82)	42(40.40)	42(40.40)	42(40.40)	42(40.40)	44(41.56)	44(41.56)	43(40.98)
60x45	41(39.82)	42(40.40)	42(40.40)	42(40.40)	42(40.40)	44(41.56)	44(41.56)	43(40.98)
Mean	41(39.82)	42(40.40)	42(40.40)	42(40.40)	42(40.40)	44(41.56)	44(41.56)	43(40.98)
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.045	0.038	0.077	0.077	0.002	0.133	0.217	0.266
CD (P=0.05)	NS	0.081	NS	NS	NS	0.282	NS	NS

Spacing (cm) (S)	Seedling length (cm)							
	Kharif				Rabi			
	NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	18.3	18.3	18.3	18.3	19	19.3	19.2	19.2
45x45	18.3	18.4	18.4	18.3	19.1	19.3	19.3	19.2
60x30	18.1	18.8	18.5	18.4	19.1	19.5	19.2	19.3
60x45	18.3	18.3	18.3	18.3	19.2	19.2	19.2	19.2
Mean	18.3	18.5	18.4	18.3	19.2	19.4	19.2	19.2
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.05	0.0435	0.087	0.087	0.052	0.0455	0.089	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.061	0.058

45×45 and 60×30 cm). Gowda et al. (2006) revealed that compared to closer spacings, the wider spacing had taken lesser days to attain 50% flowering due to the accumulation of more dry matter by utilization of nutrients, moisture, light etc., available at higher order per unit area of the plant, but in the present study flowering expressed non significant results which might be due to its continuous flowering habit. In many crops, for seed production wider spacing is recommended. Alexalbert (2007) in sweet sorghum claimed the benefit of wider spacing for development of bolder seeds that would improve the processed seed yield of the crop, which also could be attributed to the translocation of higher photosynthates to sink by improving the yield attributing plant morphological characters. Gnanamurthy et al. (1992) and Patil et al. (1996) also expressed that wider spacing improved the photosynthetic area and thereby the single plant yield. The study also highlighted that the physiological and biochemical quality characters of resultant seeds were not influenced by spacing. Similar results were obtained by Balamurugan (1993) in sunflower and Raja (2003)

Table 7. Influence of fertilizer level and spacing on seedling dry matter production and vigour index.

Spacing (cm) (S)	Dry matter production 10 seedlings^{-1}(mg)								Vigour index							
	Kharif				Rabi				Kharif				Rabi			
	NPK kgha^{-1} (F)								NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	90	92	91	91	100	102	101	101	750	769	769	762	823	871	867	853
45x45	91	91	91	91	101	101	101	101	750	771	770	763	819	876	867	854
60x30	90	93	90	91	100	103	100	101	742	786	775	764	820	876	866	855
60x45	90	92	91	91	100	102	101	101	750	769	769	763	827	867	867	854
Mean	90	92	91	91	100	102	101	101	748	774	771	764	822	872	867	854
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.014	0.065	0.106	0.129	0.014	0.065	0.106	0.129	0.343	0.898	1.505	1.795	0.136	1.559	2.550	3.119
CD (P=0.05)	NS	0.137	0.226	0.274	NS	0.137	0.226	0.274	NS	1.903	3.216	3.805	NS	3.305	5.407	6.610

Table 8. Influence of fertilizer level and spacing on seed protein content and oil content

Spacing (cm) (S)	Protein content (%)								Oil content (%)							
	Kharif				Rabi				Kharif				Rabi			
	NPK kgha^{-1} (F)								NPK kgha^{-1} (F)							
	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean	80:40:30	100:60:50	120:80:70	Mean
45x30	18.59	18.63	18.62	18.61	18.70	18.72	18.71	18.71	6.4	6.5	6.5	6.5	6.4	6.6	6.4	6.5
45x45	18.61	18.63	18.62	18.62	18.71	18.73	18.72	18.72	6.4	6.6	6.5	6.5	6.4	6.6	6.5	6.5
60x30	18.60	18.67	18.61	18.63	18.72	18.77	18.72	18.74	6.3	6.5	6.4	6.4	6.4	6.5	6.3	6.4
60x45	18.61	18.63	18.62	18.62	18.71	18.73	18.72	18.72	6.5	6.6	6.4	6.5	6.5	6.7	6.5	6.6
Mean	18.60	18.64	18.62	18.62	18.71	18.74	18.72	18.72	6.4	6.6	6.5	6.5	6.4	6.6	6.4	6.5
	S	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**	**S**	**F**	**S at F**	**F at S**
SEd	0.003	0.003	0.005	0.005	0.003	0.003	0.006	0.006	0.027	0.025	0.048	0.049	0.022	0.017	0.035	0.033
CD (P=0.05)	NS	0.006	0.012	0.012	NS	0.006	0.013	0.013	0.067	0.052	NS	NS	0.053	0.035	0.078	0.071

in rice. But, the computed pod and seed yield per hectare was low in 60×45 cm compared to 60×30 cm spacing might be due to variation in population observed with closure spacing, though the populations were more in 45×30 and 45×45 cm spacing they recorded lower yield whereas the 60×30 cm spacing recorded higher yield which was 33% higher population which compared to 60×45 cm. In seed production or any commercial production, yield is much important than individual plant yield attributing characters and the reduction in 100 seed weight was also found to be only 0.9% irrespective of seasons. Hence, spacing of 60×30 cm could be recommended for obtaining higher quality seed yield which also have economic viability. Percentage increase of major growth and yield characters of wider spacings when compared to other spacings were as shown

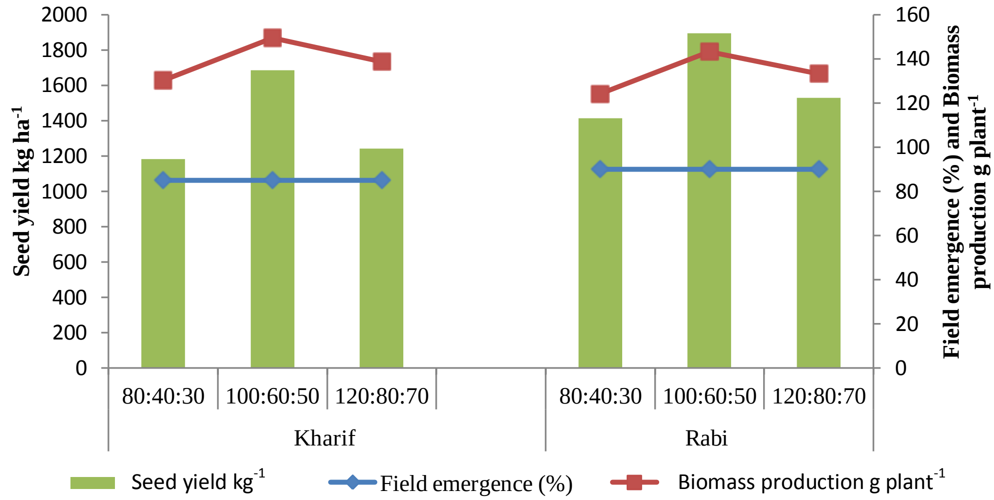

Figure 1. Effect of different fertilizer levels on growth and yield attributes.

Table 9. Comparison of yield and quality characters of different fertilizer levels.

Yield and quality characters	NPK at 100:60:50 kgha^{-1}	NPK at120:80:70 kgha^{-1}	NPK at 80:40:30 kgha^{-1}
Comparison	Better performance	Percentage decrease over 100:60:50 kg ha^{-1}	Percentage decrease over 100:60:50 kg ha^{-1}
Plant height (cm)	Highest (88.7)	2.9	6.8
Biomass production g plant^{-1}	Maximum (146.4)	7.7	15.1
Number of racemes plant^{-1}	Maximum (105)	4.3	7.5
Days to 50% flowering	1-2 days later		1-2 days earlier
Pod yield kg ha^{-1}	Maximum (2235)	20.5	27.6
Seed yield kg ha^{-1}	Maximum (1789)	22.8	27.6
100 seed weight (g)	Highest (1.404)	6.5	6.8
Germination (%)	On par (42-44)		2.0
Vigour index	Maximum (823)	0.5	4.6
Protein content (%)	Maximum (18.69)	0.1	0.2
Conclusion remarks	Optimum dose	Supra optimal dose	Sub optimal dose

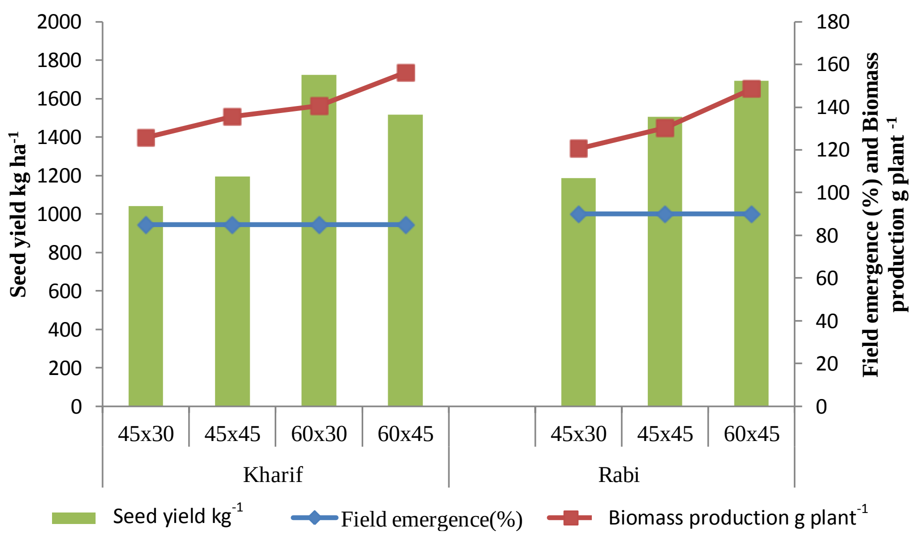

Figure 2. Effect of different spacings on growth and yield attributes.

Table 10. Comparison of yield and quality characters of different spacings.

Yield and quality characters	60x45 cm	60x30 cm	45x45 cm		45x30 cm	
Plant population /ha	37037	55556	49383		74074	
Comparison	**Higher yield attributing characters**	**Percentage decrease over 60x45 cm**	**Percentage decrease over 60x45cm**		**Percentage decrease over 60x45 cm**	
Yield attributing characters						
Plant height (cm)	Highest (91.1)	3.0	7.0		14.1	
Biomass production g $plant^{-1}$	Maximum (152.4)	10.7	14.6		23.7	
Chlorophyll content (mg 100 g^{-1})	Maximum (0.891)	2.1	6.9		8.5	
No. of branches $plant^{-1}$	Maximum (12)	4.2	13.3		18.3	
No. of racemes $plant^{-1}$	Maximum (113)	4.8	13.1		23.7	
Pod yield g $plant^{-1}$	Maximum (43.72)	7.0	14.0		48.1	
Seed yield g $plant^{-1}$	Maximum (34.98)	7.0	14.0		48.1	
Yield of the crop						
Comparison	**Decrease over 60x30cm (%)**	**60x30 cm**	**Decrease over 60x30 cm (%)**	**Decrease over 60x45 cm (%)**	**Decrease over 60x30 cm (%)**	**Decrease over 60x45 cm (%)**
Pod yield kg ha^{-1}	17.0	Maximum(2428)	30.4	16.2	42.7	30.7
Seed yield kg ha^{-1}	14.9	Maximum(1892)	28.8	16.0	40.9	30.6

in Table 10.

Conclusion

The study highlighted that for getting maximum yield with quality without much economic loss, the fertilizer recommendation of 100:60:50 NPK $kgha^{-1}$ and spacing of 60×30 cm will be optimum for babchi crop.

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