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Growth and Performance of Buckwheat as Influenced by Intercropping with Tall Growing *kharif* Crops

Gangadasari Sravana Lakshmi [a*], U. K. Hulihalli [b], Ashoka P. [c], Suma S. Biradar [d], Uma N. Kulkarni [e], Vikram Kannamreddy [f] and Girija Prasad Patnaik [g]

[a] Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad – 580005 Karnataka, India.
[b] Department of Agrometeorology, College of Agriculture, University of Agricultural Sciences, Dharwad – 580005 Karnataka, India.
[c] Krishi Vigyan Kendra, Hanumanamatti, University of Agricultural Sciences, Dharwad-580005, Karnataka, India.
[d] AICRP on Wheat, MARS, University of Agricultural Sciences, Dharwad – 580005, Karnataka, India.
[e] Department of Food Science and Nutrition, College of Community Science, University of Agricultural Sciences, Dharwad – 580005 Karnataka, India.
[f] Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India.
[g] Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar 751003, Odisha, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors GSL and UKH designed the study. Author GSL performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AP, SSB, UNK, VK, and GPP reviewed and edited the manuscript. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: lakshmisravani001@gmail.com;*

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ABSTRACT

Aims: To assess the compatibility and feasibility of buckwheat (a nutri-rich pseudocereal) when intercropped with tall-growing kharif crops in Northern transition zone of Karnataka.
Study Design: Field experiment conducted in a randomized design to evaluate the growth and performance of buckwheat under intercropping systems.
Place and Duration of Study: The study was carried out in the Northern Karnataka region, India, during two consecutive *kharif* seasons, 2021 and 2022.
Methodology: Buckwheat was intercropped with tall-growing kharif crops to analyze its growth behavior, resource utilization efficiency and adaptability under intercropping conditions.
Results: Intercropping with tall kharif crops influenced the growth of buckwheat, indicating its potential adaptability and usefulness in crop diversification and sustainable production systems.
Conclusion: Buckwheat shows promise as a compatible intercrop with tall kharif crops in Northern Karnataka, contributing to both food and nutritional security through diversification and efficient resource use.

Keywords: Buckwheat; intercropping; leaf area index; chlorophyll content (SPAD); tall growing kharif crops.

1. INTRODUCTION

"The continuous decline in per capita land availability necessitates both temporal and spatial intensification of agriculture" (Kiwia et al., 2019). "Intercropping based crop diversification serves as a key strategy to enhance productivity, optimize resource utilization, and promote sustainability. The fundamental principle of intercropping lies in cultivating two or more crops together, assuming that their complementary resource use allows them to utilize the environment more efficiently and achieve higher yields" (Yadav et al., 2015). To meet the increasing food demand of the growing population, there is a pressing need to explore alternative crops beyond the conventional ones within diverse cropping systems. Despite their nutritional and health benefits, many food crops remain underutilized. Among them, pseudocereals, often termed "nutria-rich crops," have received little cultivation attention. Buckwheat, a pseudocereal from the Polygonaceae family, traditionally grown in northern India and recently introduced in North Karnataka, is a promising short duration crop that can easily integrate into various cropping systems, making it a potential "smart crop" for intercropping. As a relatively new crop in this region, assessing the suitability of buckwheat with different tall growing kharif crops in the Northern Transition Zone of Karnataka is essential to determine its compatibility and productivity in established systems. Intercropping will have influence on the growth and development of both the component crops. Plant density and arrangement plays a crucial role which decides the compatibility or competition between the component crops. Hence, with this objective, an experiment was conducted at MARS, Dharwad, during two consecutive years (2021 and 2022) to study the influence of intercropping buckwheat with tall growing kharif crops such as maize, sweet corn, baby corn, sunflower, and chia in different row ratios on the morphological and phenological growth, and overall performance of buckwheat.

2. MATERIALS AND METHODS

The study was conducted on black clayey soil at MARS, UAS Dharwad, characterized by neutral pH, low nitrogen (255.5 kg ha^{-1}), medium phosphorus (29.8 kg ha^{-1} P_2O_5), and high potassium (330.3 kg ha^{-1} K_2O). The experiment was carried out during the kharif seasons of 2021 and 2022, comprising 16 treatments arranged in a randomized block design with a factorial concept and three replications. Buckwheat was introduced as an intercrop with various tall growing kharif crops such as maize, sweet corn, baby corn, sunflower, and chia in 1:1 and 2:4 row proportions, along with their respective sole crops for comparison. The two experimental factors included crop species (Factor A) and row ratios (Factor B). Treatment details include T_1-Maize+buckwheat (1:1), T_2- Sweet corn+buckwheat (1:1), T_3-Baby corn+buckwheat (1:1), T_4-Sunflower+buckwheat (1:1), T_5-Chia+buckwheat (1:1), T_6- Maize+buckwheat (2:4), T_7-Sweet corn+buckwheat (2:4), T_8- Baby corn+buckwheat (2:4), T_9-Sunflower+buckwheat (2:4), T_{10}-Chia+buckwheat (2:4), T_{11}- Sole buckwheat, T_{12}-Sole maize, T_{13}-Sole sweet corn,

T_{14}- Sole Baby corn, T_{15}- Sole Sunflower, T_{16}- Sole chia. Sole crops population was not disturbed and 50 per cent of buckwheat was introduced between the rows of the main crop. In the 2:4 intercropping ratio, the spacing of the main crops was adjusted to accommodate the buckwheat rows, which resulted in a reduced main crop population compared to their sole cropping. For maize, sweet corn, baby corn, sunflower, and chia intercropped with buckwheat in the 2:4 system, spacing was maintained at 30 cm between two rows of the main crop (paired rows) and 120 cm between two sets of paired rows (30 × 120 cm), where four rows of buckwheat were accommodated between the paired rows. buckwheat were planted. The data regarding the morphological growth (LAI, SPAD values, plant height and dry matter production) phenological growth (days to 50 per cent flowering and days to maturity) were collected periodically following the standard procedures.

3. RESULTS AND DISCUSSION

3.1 Growth of Buckwheat

3.1.1 Leaf area index

With respect to LAI significant difference was recorded in buckwheat at all stages of crop growth. Among five crops, at harvest, buckwheat recorded higher LAI when intercropped with maize (1.61) and was on par with buckwheat intercropped with sweet corn (1.55) and baby corn (1.50). Sole crop recorded higher LAI (2.02) compared to intercropping ratios at all stages of crop growth. Better growth of the plant with higher LAI which increased the photosynthetic area, increased light absorption and hence more dry matter accumulation which lead to increased growth and yield in sole buckwheat compared to intercropped one. Similar findings were reported by Salehi et al. (2018a), who observed a reduction in leaf area index (LAI) and dry matter in intercropped systems compared to sole cropping. Among the row ratios, buckwheat intercropped in the 2:4 ratio recorded a higher LAI (1.69) than the 1:1 ratio (1.29) at harvest (Table 1). Whereas the interaction effect of buckwheat intercropped with tall growing crops in different row ratios recorded no significant difference among the treatments with respect to LAI. However, at harvest, 2:4 maize+buckwheat recorded higher LAI (1.84) and was statistically similar with buckwheat in sweet corn (1.76) and baby corn (1.70) in 2:4 ratio. However, buckwheat intercropped with sunflower in the 1:1 ratio (1.17) recorded a lower leaf area index (LAI) compared to other treatments.

3.1.2 Chlorophyll content (SPAD value)

Intercropping buckwheat with various crops such as maize, sweet corn, baby corn, sunflower, and chia did not show any significant variation in chlorophyll content across different growth stages. However, a significant effect of row ratio on SPAD values was observed (Table 2). Buckwheat grown in the 2:4 intercropping ratio recorded a higher SPAD value (42.2) than the sole crop (41.2), both being statistically comparable, which could be attributed to the intercrop benefiting from the higher nitrogen applied to the main crop. Conversely, buckwheat grown in the 1:1 ratio with all crops recorded a lower SPAD value (34.4) at harvest, mainly due to shading by the taller companion crops that restricted its growth and reduced chlorophyll accumulation. Reduced LAI, chlorophyll content and hence reduced growth and dry matter production which in turn lead to reduced yield of buckwheat. A similar observation was reported by Nasir et al. (2011), who noted that the growth of short duration crops was suppressed when intercropped with tall, late maturing crops. The interaction effect of intercropping buckwheat with different crops under varied row ratios showed no significant differences among the treatments at any stage of crop growth. Among the intercropping ratios, buckwheat intercropped with sunflower in 1:1 ratio recorded decreased plant height and lack of light reaching buckwheat reduced the leaf development and subsequently LAI was reduced by 35 per cent and hence causing decreased photosynthesis. This decrease was also fueled by decreased SPAD value and reduced dry matter production (60% decrease) which in turn reduced the grain and straw yield compared to sole crop. Similar results were reported by Silwana and Lucas (2002) They reported decrease in LAI of bean intercropped with maize. Similarly, Joyah and Jimba (2011) reported that vegetative growth is reduced in intercropped cowpea than that of sole crop.

3.1.3 Plant height and dry matter production

Growth parameters of buckwheat like plant height and dry matter production were also influenced by intercropping. Plant height was higher in intercropped buckwheat with maize compared to sole crop. Competition for light with main crop in initial stages caused an increase in the plant height but at later stages, due to

Table 1. Leaf area index (LAI) of buckwheat (cm) at harvest as influenced by intercropping with tall growing *kharif* crops

A/B	Leaf Area Index																	
	2021						2022						Pooled					
	A_1	A_2	A_3	A_4	A_5	Mean	A_1	A_2	A_3	A_4	A_5	Mean	A_1	A_2	A_3	A_4	A_5	Mean
B_1	1.36	1.31	1.28	1.13	1.20	1.26	1.42	1.38	1.32	1.20	1.29	1.32	1.39	1.35	1.30	1.17	1.25	1.29
B_2	1.78	1.70	1.64	1.48	1.52	1.62	1.89	1.82	1.76	1.62	1.68	1.75	1.84	1.76	1.70	1.55	1.60	1.69
Mean	1.57	1.505	1.46	1.31	1.36		1.66	1.6	1.54	1.41	1.49		1.61	1.55	1.50	1.36	1.42	
Control	1.98						2.05						2.02					
SV	S.Em. ±			C.D. (p=0.05)			S.Em ±			C.D. (p=0.05)			S.Em. ±			C.D. (p=0.05)		
A	0.04			0.11			0.05			0.14			0.04			0.12		
B	0.02			0.07			0.03			0.09			0.03			0.08		
AXB	0.05			NS			0.07			NS			0.06			NS		
Control	0.05			0.15			0.07			0.2			0.06			0.17		

Factor A: Crops *A_1: Maize+BW* *A_2: Sweet corn+BW* *A_3: Baby corn+BW* *A_4: Sunflower+BW* *A_5: Chia+BW*
Factor B: Row ratios *B_1: 1:1* *B_2: 2:4* *Control: Sole Buckwheat* *SV: Source of variation* *BW:Buckwheat* *NS: Non significant*

Table 2. Chlorophyll content (SPAD value) of buckwheat at harvest as influenced by intercropping with tall growing *kharif* crops

A/B	Chlorophyll content (SPAD value)																	
	2021						2022						Pooled					
	A_1	A_2	A_3	A_4	A_5	Mean	A_1	A_2	A_3	A_4	A_5	Mean	A_1	A_2	A_3	A_4	A_5	Mean
B_1	34.5	33.8	33.2	32.5	32.9	33.4	36.8	36.2	35.5	33.8	34.4	35.3	35.7	35.0	34.4	33.2	33.7	34.4
B_2	42.6	41.8	41.3	39.7	40.4	41.2	44.5	44.2	43.6	41.4	42.5	43.2	43.6	43.0	42.5	40.6	41.5	42.2
Mean	38.6	37.8	37.3	36.1	36.7		40.7	40.2	39.6	37.6	38.5		39.6	39.0	38.4	36.9	37.6	
Control	39.8						42.6						41.2					
SV	S.Em. ±			C.D. (p=0.05)			S.Em ±			C.D. (p=0.05)			S.Em. ±			C.D. (p=0.05)		
A	1.0			NS			1.2			NS			1.1			NS		
B	0.6			1.8			0.8			2.3			0.7			2.0		
AXB	1.4			NS			1.7			NS			1.5			NS		
Control	1.3			3.8			1.7			4.9			1.5			4.3		

Factor A: Crops *A_1: Maize+BW* *A_2: Sweet corn+BW* *A_3: Baby corn+BW* *A_4: Sunflower+BW* *A_5: Chia+BW*
Factor B: Row ratios *B_1: 1:1* *B_2: 2:4* *Control: Sole Buckwheat* *SV: Source of variation* *BW:Buckwheat* *NS: Non significant*

shading effect from the main crops, growth of buckwheat was suppressed and hence reduced plant height, leaf area index which in turn reduce the photosynthetic surface and reduced dry matter accumulation compared to sole crop (Fig. 1). Buckwheat intercropped with all the crops recorded a reduction in growth and yield but the per cent reduction was less in maize intercropping system. Similar results were reported by Idoko et al. (2018) that cowpea intercropped with maize shown a reduction in the growth parameters like height, LAI and dry weight compared to sole cowpea. The sole crop recorded higher growth parameters and consequently better yield than the intercropped treatments, mainly due to the absence of competition from the main crops. In contrast, buckwheat intercropped with sunflower in the 1:1 ratio exhibited reduced growth and lower yield compared to other treatments, which could be attributed to the shading effect of the taller sunflower plants that suppressed buckwheat growth and ultimately decreased yield.

3.2 Phenology of Buckwheat

3.2.1 Days to 50 per cent flowering and maturity

Intercropping buckwheat with tall growing kharif crops influenced not only its morphological growth but also its phenological development. However, days to 50 percent flowering in buckwheat were not significantly affected either by the type of intercrop or by different row ratios (Table 3). The interaction effect between crops and row ratios also showed no significant variation in days to 50 percent flowering, as the initial 25 to 30 days of growth, corresponding to the period of flowering initiation, remained unaffected by intercropping. However, the values ranged from 34.7 to 32.7 days among the treatments. Intercropping of buckwheat with different tall crops also had recorded no notable difference in days taken to maturity. Whereas, among the row ratios sole crop matured earlier (71.3) compared to intercropped ratios and was on par with buckwheat intercropped in 2:4 ratio (73.6). However, buckwheat in 1:1 ratio recorded delayed maturity (78.5) compared to other treatments. Similar results were reported by (Kumar et al., 2017).

Interaction effect of buckwheat intercropping with different crops in varied ratios did not show any significant difference among the treatments. However, the values ranged from 73.3 to 79.3 days (Table 4). Buckwheat intercropped with sunflower in 1:1 ratio took more days (79.9) to attain maturity that buckwheat intercropped with maize in 2:4 ratio (73.3 days). This difference was due to the reduced light interception, decreased growth which prolonged the

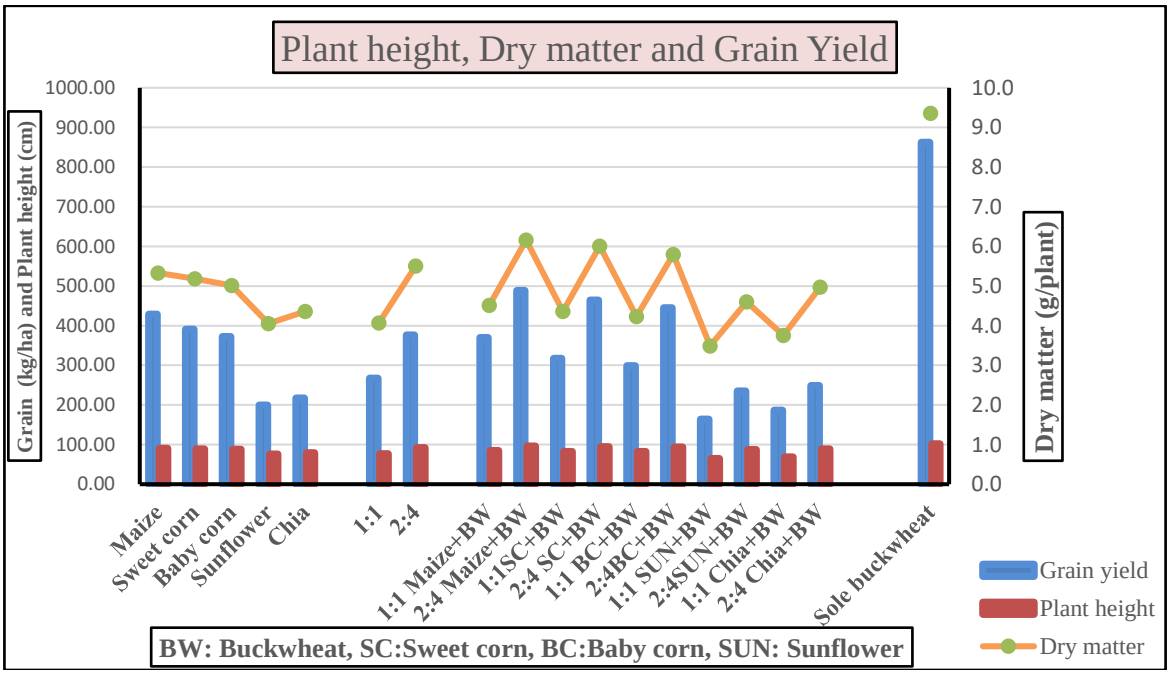

Fig. 1. Plant height, dry matter production and grain yield of buckwheat as influenced by intercropping with tall growing *kharif* crops

Table 3. Days to 50 per cent flowering in buckwheat as influenced by intercropping with tall growing *kharif* crops

A/B	Days to 50 per cent flowering (days)																	
	2021						2022						Pooled					
	A_1	A_2	A_3	A_4	A_5	Mean	A_1	A_2	A_3	A_4	A_5	Mean	A_1	A_2	A_3	A_4	A_5	Mean
B_1	32.2	32.6	33.0	33.8	33.6	33.0	34.0	34.5	34.2	35.0	33.6	34.3	33.1	33.6	33.6	34.4	33.6	33.7
B_2	32.0	32.5	32.8	34.0	33.2	32.9	33.6	34.0	34.2	35.3	34.8	34.4	32.8	33.3	33.5	34.7	34.0	33.6
Mean	32.1	32.6	32.9	33.9	33.4		33.8	34.3	34.2	35.2	34.2		33.0	33.4	33.6	34.5	33.8	
Control	31.8						33.5						32.7					
SV	S.Em. ±			C.D. (p=0.05)			S.Em ±			C.D. (p=0.05)			S.Em. ±			C.D. (p=0.05)		
A	0.8			NS			1.0			NS			0.9			NS		
B	0.5			NS			0.6			NS			0.6			NS		
AXB	1.2			NS			1.4			NS			1.3			NS		
Control	1.1			NS			1.4			NS			1.3			NS		

Factor A: Crops *A_1: Maize+BW* *A_2: Sweet corn+BW* *A_3: Baby corn+BW* *A_4: Sunflower+BW* *A_5: Chia+BW*
Factor B: Row ratios *B_1: 1:1* *B_2: 2:4* *Control: Sole Buckwheat* *SV: Source of variation* *BW:Buckwheat* *NS: Non significant*

Table 4. Days to maturity (days) in buckwheat as influenced by intercropping with tall growing *kharif* crops

A/B	Days to maturity (days)																	
	2021						2022						Pooled					
	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**Mean**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Mean**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Mean**
B_1	76.5	77.2	77.5	78.5	78.0	77.5	78.8	79.0	79.3	80.0	80.0	79.4	77.7	78.1	78.4	79.3	79.0	78.5
B_2	72.5	72.0	72.0	73.0	72.8	72.5	74.0	74.5	74.5	75.5	75.3	74.8	73.3	73.3	73.3	74.3	74.1	73.6
Mean	74.5	74.6	74.8	75.8	75.4		76.4	76.8	76.9	77.8	77.7		75.5	75.7	75.8	76.8	76.5	
Control	70						72.5						71.25					
SV	S.Em. ±			C.D. (p=0.05)			S.Em ±			C.D. (p=0.05)			S.Em. ±			C.D. (p=0.05)		
A	1.9			NS			2.3			NS			2.1			NS		
B	1.2			3.5			1.4			4.3			1.3			3.9		
AXB	2.7			NS			3.2			NS			2.9			NS		
Control	2.6			NS			3.2			NS			2.8			NS		

Factor A: Crops *A_1: Maize+BW* *A_2: Sweet corn+BW* *A_3: Baby corn+BW* *A_4: Sunflower+BW* *A_5: Chia+BW*
Factor B: Row ratios *B_1: 1:1* *B_2: 2:4* *Control: Sole Buckwheat* *SV: Source of variation* *BW:Buckwheat* *NS: Non significant*

vegetative phase of the crop and hence delayed the maturity. Similar reason was given by Owonubi and Yusuf (1986). Mariga (1990) also reported that in intercropping system of cowpea and maize, delayed maturity of cowpea was recorded compared to sole cowpea which could be as a result of the shading effect of the taller maize plant which must have delayed flowering and maturity in cowpea.

4. CONCLUSION

Buckwheat showed better growth performance when intercropped with maize in the 2:4 ratio, followed by sweet corn and baby corn in the same proportion, compared to the 1:1 row ratio. Higher leaf area index (LAI), chlorophyll content, plant height, dry matter accumulation, and yield were observed in buckwheat intercropped with maize in the 2:4 ratio, while buckwheat intercropped with sunflower in the 1:1 ratio exhibited reduced growth and consequently lower yield. However sole buckwheat performed well compared to intercropped treatments. Maturity in buckwheat was delayed in the intercropping treatments compared to the sole crop. Buckwheat intercropping with maize was found suitable for the better growth of buckwheat compared to other tall growing crops.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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