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RESEARCH PAPER

Influence of Buckwheat intercropping on growth parameters of Chilli (*Capsicum annum* L.)

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Abstract: A field experiment was conducted during *kharif* 2022 and 2023 at the Main Agricultural Research Station, Dharwad Karnataka to study the intercropping of buckwheat with chilli under Northern Transition Zone of Karnataka. The experiment was laid out in randomized complete block design with 9 treatments and 3 replications. The treatments were as follows, T_1: Chilli (90 × 90 cm) + Buckwheat (1:1), T_2: Chilli (90 × 90 cm) + Buckwheat (1:2), T_3: Chilli (120 × 60 cm) + Buckwheat (1:3), T_4: Paired row Chilli (60-90-60 cm) + Buckwheat (2:2), T_5: Paired row Chilli (60-120-60 cm) + Buckwheat (2:3), T_6: Chilli (90 × 90 cm) + Green gram (1:1), T_7: Sole Chilli (90 × 90 cm), T_8: Sole Buckwheat (30 × 10 cm), T_9: Sole Green gram (30 × 10cm). Chilli recorded higher plant height, Leaf area index, dry matter production and number of branches plant^{-1} in sole chilli. Among different intercropping systems chilli (90 × 90 cm) + buckwheat (1:1) recorded significantly higher plant height, Leaf area index, dry matter production and number of branches plant^{-1} of chilli. Lower plant height, Leaf area index, dry matter production and number of branches plant^{-1} were recorded with chilli (120 × 60 cm) + buckwheat (1:3) (T_3).

Key words*:* Buckwheat, Chilli, Intercropping, Plant height

Introduction

Growing two or more crops at the same time on the same plot of land is known as intercropping, and it has drawn more and more attention as a sustainable way to maximize land production, improve resource use efficiency and lessen the burden of pests and diseases. In intensive cropping systems, where increasing yield per unit area is crucial for both ecological and economic sustainability, it is especially beneficial (Zou *et al*., 2021). Combining high-value crops with short-duration cover or pseudo-cereal crops is one of the intercropping systems that offers the most potential for both agronomic and financial gains. The economically important spice and vegetable crop known as chilli (*Capsicum annuum* L.) is widely grown for its spicy fruits that are high in vitamins and capsaicin. But in the early phases of growth, it is vulnerable to pest infestation, weed competition and nutrient depletion. By growing chilli alongside appropriate companion crops, you can improve soil fertility, reduce weed growth and create a more favourable microclimate (Khatun *et al*., 2020). Buckwheat (*Fagopyrum esculentum* Moench.) is a fast-growing pseudo-cereal that is well-known for its capacity to flourish in marginal soils, suppress weeds by rapidly developing a canopy and sustain beneficial insect populations because of its abundant flowering (Salehi *et al*., 2018). Buckwheat and chilli are ecologically complementary, which makes intercropping them a potentially successful tactic. The short growth period and shallow root system of buckwheat may lessen competition for resources while providing agronomic advantages like enhanced biodiversity, decreased erosion and better soil structure. The agronomic interactions, yield benefits and economic feasibility of chilli-buckwheat intercropping under various agro-ecological settings have not received much attention, despite its potential. In order to assess the productivity and resource usage efficiency of chilli-buckwheat intercropping under Northern Transition Zone of Karnataka, the current study was conducted.

Material and methods

The field experiment was conducted during the *kharif* seasons of 2022 and 2023 at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, Karnataka. The experimental site is situated at 15°262 N latitude, 75°072 E longitude and an elevation of 678 meters above mean sea level. The location falls under the Northern Transition Zone of Karnataka, which lies between the Western Hilly Zone and the Northern Dry Zone. The total rainfall received during crop growth period of 2022 was 1101.06 mm and 507.00 mm during 2023. The soil at the experimental site is classified as clay in texture. In 2022, the soil was neutral to slightly alkaline in reaction (pH 7.86), with normal electrical conductivity (0.26 dS m^{-1}), medium organic carbon content (0.52%), low in available nitrogen (265.53 kg N ha^{-1}), medium in available phosphorus (30.28 kg P_2O_5ha^{-1}) and high in available potassium (350.43 kg K_2O ha^{-1}). Similarly, in 2023, the soil was neutral to slightly alkaline (pH 7.61), with an electrical conductivity of 0.25 dS m^{-1}, organic carbon content of 0.51%, low available nitrogen (278.30 kg N ha^{-1}), medium phosphorus content (32.04 kg P_2 O_5ha^{-1}) and high potassium content (367.06 kg K_2 O ha^{-1}). The treatments included was as followed, T_1: Chilli (90 × 90 cm) + Buckwheat (1:1), T_2: Chilli (90 × 90 cm) + Buckwheat (1:2), T_3: Chilli (120 × 60 cm) + Buckwheat (1:3), T_4: Paired row Chilli (60-90-60 cm) + Buckwheat (2:2), T_5: Paired row Chilli (60-120-60 cm) + Buckwheat (2:3), T_6: Chilli (90 × 90 cm) + Green gram (1:1), T_7: Sole Chilli (90 × 90 cm), T_8: Sole Buckwheat (30 × 10 cm), T_9:

Sole Green gram (30 ×10cm). The spacing followed for buckwheat and green gram was 30 × 10 cm. The land was prepared to a fine seedbed by ploughing and harrowing. Based on plant population the recommended dose of fertilizer was applied to each plot. The recommended dose of fertilizer for chilli- 100:50:50, buckwheat- 40:20:10 and green gram- 25:50:0 N, P_2O_5 and K_2O kg ha^{-1}, respectively were used. The varieties used were byadagi dabbi (chilli), Dharwad selection-1 (buckwheat) and IPM -2-14 (green gram). All other agronomic practices were followed as per the package of practice. Plant height was measured from the ground level to the tip of main shoot from five plants and the mean plant height was worked out and expressed in cm. Total number of branches produced per plant was counted and mean was taken as number of branches per plant. Plants at different stages were cut close to the ground for the determination of dry matter production by each plant. Then they were dried at 70 ^{0}C in hot air oven until the constant weight was attained and the oven dry weight of plant was recorded and expressed in grams per plant. Leaf area was measured by the disc method as suggested by Vivekanandan *et al.* (1972) at 60 DAS, 120 DAS and at harvest. Leaf area index is defined as assimilatory surface area per unit land area (Watson, 1952).

Results and discussion

Plant height

Data on the plant height of chilli at 60, 120 DAS and at harvest as influenced by intercropping of buckwheat at different row ratios is represented in the Table 1. Sole chilli (90 × 90 cm) recorded significantly higher plant height of chilli (46.9, 67.9 and 73.3 cm at 60, 120 DAS and at harvest, respectively). Among different intercropping systems chilli (90 × 90 cm) + buckwheat (1:1) recorded significantly higher plant height of chilli (41.3, 61.6 and 67.1 cm at 60, 120 DAS and at harvest, respectively). Significantly lower plant height of chilli (36.6, 56.4 and 61.8 cm at 60, 120 DAS and at harvest, respectively) was recorded with chilli (120 × 60 cm) + buckwheat (1:3) and this was on par with paired row chilli (60-120-60 cm) + buckwheat (2:3) (T_5) (37.4, 58.0 and 62.6 cm at 60, 120 DAS and at harvest, respectively). The results indicate that sole chilli planting consistently produced the tallest plants across all growth stages, suggesting that intercropping with buckwheat may suppress chilli plant height. This could be attributed to competition for resources such as light, water and nutrients, particularly in denser intercropping systems like T_3, which consistently showed the lowest plant height. The competitive effects of intercropping are well-documented in the literature. For instance, Banik *et al.* (2006) reported that intercropping systems can reduce the growth of the main crop due to resource competition, particularly when the intercrop has a faster growth rate or higher density, as seen with buckwheat in T_3. Among intercropping treatments, T_1 and T_6 showed relatively better performance, this suggests that a balanced intercropping ratio (1:1) may minimize competition compared to higher buckwheat densities. The paired row treatments (T_4 and T_5) also showed moderate

Table 1. Plant height of chilli as influenced by buckwheat intercropping at different growth stages

Treatment	Plant height (cm)								
	60 DAS			120 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1 - Chilli (90 × 90 cm) + Buckwheat (1:1)	44.0^{ab}	38.6^{b}	41.3^{bc}	65.2^{b}	58.0^{b}	61.6^{b}	70.1^{b}	64.1^{b}	67.1^{b}
T_2 - Chilli (90 × 90 cm) + Buckwheat (1:2)	43.2^{b}	36.2^{bc}	39.7^{bc}	64.9^{b}	55.0^{b}	59.9^{b}	67.9^{bc}	61.9^{b}	64.9^{bc}
T_3 - Chilli (120 × 60 cm) + Buckwheat (1:3)	39.9^{b}	33.4^{c}	36.6^{c}	60.1^{b}	52.0^{b}	56.4^{c}	64.8^{c}	58.8^{b}	61.8^{c}
T_4 - Paired row chilli (60-90-60 cm) + Buckwheat (2:2)	43.1^{b}	35.5^{bc}	39.3^{bc}	64.5^{b}	54.6^{b}	59.5^{b}	67.5^{bc}	61.2^{b}	64.3^{bc}
T_5 - Paired row chilli (60-120-60 cm) + Buckwheat (2:3)	40.7^{b}	34.1^{c}	37.4^{bc}	62.5^{b}	53.5^{b}	58.0^{b}	65.9^{bc}	59.4^{b}	62.6^{bc}
T_6 - Chilli (90 × 90 cm) + Green gram (1:1)	45.0^{ab}	38.9^{b}	41.9^{b}	65.0^{b}	56.8^{b}	60.9^{b}	69.9^{b}	62.8^{b}	66.4^{bc}
T_7 - Sole chilli (90 × 90 cm)	50.0^{a}	43.8^{a}	46.9^{a}	71.5^{a}	64.2^{a}	67.9^{a}	75.9^{a}	70.7^{a}	73.3^{a}
S.Em±	1.9	1.3	1.4	1.9	1.8	1.6	1.5	1.6	1.5

Means followed by the same letter(s) within column are not significantly differed by DMRT (p=0.05)

Table 2. Leaf area index of chilli as influenced by buckwheat intercropping at different growth stages

Treatment	Leaf area index								
	60 DAS			120 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1 - Chilli (90 × 90 cm) + Buckwheat (1:1)	0.56^{b}	0.53^{b}	0.54^{b}	2.23^{b}	1.91^{b}	2.07^{b}	1.77^{b}	1.59^{b}	1.68^{b}
T_2 - Chilli (90 × 90 cm) + Buckwheat (1:2)	0.54^{bc}	0.52^{b}	0.53^{bc}	2.08^{cd}	1.80^{c}	1.94^{c}	1.69^{b}	1.50^{bc}	1.59^{bc}
T_3 - Chilli (120 × 60 cm) + Buckwheat (1:3)	0.51^{c}	0.49^{b}	0.50^{c}	1.84^{e}	1.53^{e}	1.69^{e}	1.53^{c}	1.34^{d}	1.43^{d}
T_4 - Paired row chilli (60-90-60 cm) + Buckwheat (2:2)	0.54^{bc}	0.52^{b}	0.53^{bc}	2.17^{bc}	1.81^{bc}	1.99^{bc}	1.65^{bc}	1.49^{b-d}	1.57^{bc}
T_5 - Paired row chilli (60-120-60 cm) + Buckwheat (2:3)	0.52^{c}	0.50^{b}	0.51^{bc}	1.98^{d}	1.66^{d}	1.82^{d}	1.57^{c}	1.43^{cd}	1.50^{cd}
T_6 - Chilli (90 × 90 cm) + Green gram (1:1)	0.55^{b}	0.53^{b}	0.54^{b}	2.18^{bc}	1.88^{bc}	2.03^{bc}	1.72^{b}	1.56^{bc}	1.64^{b}
T_7 - Sole chilli (90 × 90 cm)	0.60^{a}	0.58^{a}	0.59^{a}	2.40^{a}	2.10^{a}	2.25^{a}	1.91^{a}	1.79^{a}	1.85^{a}
S.Em±	0.01	0.01	0.01	0.04	0.03	0.03	0.04	0.04	0.03

Means followed by the same letter(s) within column are not significantly differed by DMRT (p=0.05)

Table 3. Total dry matter of chilli as influenced by buckwheat intercropping at different growth stages

Treatment	Total dry matter (g plant^{-1})								
	60 DAS			120 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1 - Chilli (90 × 90 cm) + Buckwheat (1:1)	51.02^{a}	48.10^{b}	49.87^{bc}	114.12^{ab}	112.20^{a}	113.16^{ab}	198.60^{a}	195.20^{a}	196.90^{a}
T_2 - Chilli (90 × 90 cm) + Buckwheat (1:2)	50.50^{a}	46.60^{b}	49.35^{c}	112.30^{b}	110.41^{a}	111.35^{b}	197.60^{a}	194.20^{a}	195.90^{a}
T_3 - Chilli (120 × 60 cm) + Buckwheat (1:3)	42.63^{b}	38.76^{c}	41.48^{d}	94.13^{c}	90.07^{b}	92.10^{c}	181.90^{b}	178.50^{b}	180.20^{b}
T_4 - Paired row chilli (60-90-60 cm) + Buckwheat (2:2)	38.76^{c}	36.20^{d}	37.61^{e}	88.10^{d}	85.50^{bc}	86.79^{d}	170.80^{c}	167.40^{c}	169.10^{c}
T_5 - Paired row chilli (60-120-60 cm) + Buckwheat (2:3)	37.73^{c}	33.83^{e}	36.58^{e}	85.90^{d}	81.86^{c}	83.88^{d}	151.90^{d}	148.50^{d}	150.20^{d}
T_6 - Chilli (90 × 90 cm) + Green gram (1:1)	52.06^{a}	47.80^{b}	50.91^{b}	113.90^{ab}	111.72^{a}	112.81^{ab}	198.00^{a}	194.60^{a}	196.30^{a}
T_7 - Sole chilli (90 × 90 cm)	53.87^{a}	50.60^{a}	52.72^{a}	117.98^{a}	115.51^{a}	116.74^{a}	201.60^{a}	198.20^{a}	199.90^{a}
S.Em±	1.22	0.59	1.22	1.28	1.66	1.31	2.39	2.39	2.39

Means followed by the same letter(s) within column are not significantly differed by DMRT (p=0.05)

suppression of chilli height, likely due to altered spatial arrangements affecting light interception and root competition. Similar findings were noted by Singh *et al.* (2017), who observed that wider spacing in intercropping systems mitigates competition and improves main crop growth.

Leaf area index (LAI)

Data pertaining to the leaf area index of chilli at 60, 120 DAS and at harvest as influenced by intercropping at different row ratios of buckwheat is represented in the Table 2. Significantly higher leaf area index (0.59, 2.25 and 1.85 at 60, 120 DAS and at harvest, respectively) of chilli was recorded with sole chilli (90 × 90 cm) (T_7). Chilli (90 × 90 cm) + buckwheat (1:1) (T_1) recorded significantly higher leaf area index (0.54, 2.07 and 1.68 at 60, 120 DAS and at harvest, respectively) among different intercropping treatments which was on par with chilli (90 × 90 cm) + green gram (1:1) (T_6) (00.54, 2.03 and 1.64 at 60, 120 DAS and at harvest, respectively). Chilli (120 × 60 cm) + buckwheat (1:3) (T_3) recorded significantly lower leaf area index (0.50, 1.69 and 1.43 at 60, 120 DAS and at harvest, respectively). The results demonstrate that sole chilli consistently exhibited the higher LAI across all growth stages, likely due to reduced competition for resources such as light, water and nutrients compared to intercropping systems. Intercropping with buckwheat reduced LAI, with T_3 consistently showing the lowest values, possibly due to higher competition from the denser buckwheat population. This aligns with findings by Singh *et al.* (2018), who reported that intercropping systems often lead to reduced LAI in the main crop due to competition for resources, particularly light, which is critical for leaf expansion.

T_1 and T_6 performed better than other intercropping treatments, suggesting that a balanced intercropping ratio (1:1) minimizes competition while allowing complementary resource use. This is supported by Kumar and Meena (2020), who noted that intercropping legumes like green gram with cereals or vegetables can enhance resource use efficiency, though it may still reduce the LAI of main crop compared to sole cropping.

Total dry matter production

Total dry matter production of chilli at 60, 120 DAS and at harvest as influenced by intercropping of buckwheat at different row ratios is represented in the Table 3. Total dry matter production was significantly higher with sole chilli (90 × 90 cm) (T_7) (52.72, 116.74 and 199.90 g plant^{-1} at 60, 120 DAS and at harvest, respectively). Significantly higher total dry matter production (49.87, 113.16 and 196.90 g plant^{-1} at 60, 120 DAS and at harvest, respectively) was recorded with chilli (90 × 90 cm) + buckwheat (1:1) (T_1) among different intercropping treatments. Significantly lower total dry matter production (41.48, 92.10 and 180.20 g plant^{-1} at 60, 120 DAS and at harvest, respectively) was recorded with chilli (120 × 60 cm) + buckwheat (1:3) (T_3). The results highlight the impact of intercropping systems on chilli dry matter, with sole chilli consistently outperforming intercropped treatments due to the absence of competition for resources. The comparable performance of T_1 and T_6 suggests that a balanced intercropping ratio (1:1) minimizes competition while potentially benefiting from complementary interactions, such as weed suppression by buckwheat (Singh *et al*., 2018). Buckwheat, known for its rapid growth, likely exerted competitive pressure in treatments with

Table 4. Number of branches of chilli as influenced by buckwheat intercropping at different growth stages

Treatment	Number of branches (plant^{-1})								
	60 DAS			120 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T - Chilli (90 × 90 cm) + Buckwheat (1:1)	3.67^{b}	3.66^{b}	3.66^{b}	6.98^{b}	5.54^{b}	6.26^{b}	8.22^{b}	8.44^{b}	8.33^{b}
T^1 - Chilli (90 × 90 cm) + Buckwheat (1:2)	3.44^{b}	3.33^{c}	3.38^{cd}	6.00^{c}	4.98^{bc}	5.49^{c}	8.00^{bc}	7.89^{c}	7.94^{c}
T^2 - Chilli (120 × 60 cm) + Buckwheat (1:3)	3.00^{c}	2.80^{e}	2.90^{e}	4.90^{d}	3.52^{d}	4.21^{d}	7.33^{d}	7.00^{e}	7.16^{d}
T^3 - Paired row chilli (60-90-60 cm) + Buckwheat (2:2)	3.44^{b}	3.11^{d}	3.27^{d}	5.97^{c}	4.67^{c}	5.32^{c}	7.88^{c}	7.90^{c}	7.88^{c}
T^4 - Paired row chilli (60-120-60 cm) + Buckwheat (2:3)	3.00^{c}	2.89^{e}	2.94^{e}	5.01^{d}	3.98^{d}	4.49^{d}	7.33^{d}	7.52^{d}	7.42^{d}
T^5 - Chilli (90 × 90 cm) + Green gram (1:1)	3.44^{b}	3.55^{b}	3.49^{bc}	6.77^{b}	5.12^{bc}	5.94^{b}	8.11^{bc}	8.22^{b}	8.16^{bc}
T^6 - Sole chilli (90 × 90 cm)	4.00^{a}	3.88^{a}	3.94^{a}	7.45^{a}	6.52^{a}	6.98^{a}	8.66^{a}	8.77^{a}	8.71^{a}
7									
S.Em±	0.09	0.05	0.07	0.10	0.21	0.12	0.09	0.09	0.09

Means followed by the same letter(s) within column are not significantly differed by DMRT (p=0.05) higher intercropping ratios, reducing chilli dry matter production, especially in paired row systems (T_4, T_5) where spatial constraints may have intensified resource competition (Iqbal *et al*., 2019).

The lower dry matter in T_3, T_4 and T_5 aligns with findings from Kumar *et al*. (2020), who reported that dense intercropping systems can reduce main crop biomass due to shading and nutrient competition. The paired row systems likely exacerbated this effect by altering light interception and root interactions, as noted by Reddy *et al*. (2021). The slight year-wise variation could be attributed to differences in rainfall, as intercropping systems are sensitive to environmental factors (Patel *et al*., 2022).

Number of branches (plant^{-1})

Results of data regarding number of branches plant^{-1} of chilli at 60, 120 DAS and at harvest as influenced by intercropping at different row ratios of buckwheat are represented in the Table 4. Number of branches plant^{-1} was recorded significantly higher (3.94, 6.98 and 8.71 at 60, 120 DAS and at harvest, respectively) with sole chilli (90 × 90 cm) (T_7). Chilli (90 × 90 cm) + buckwheat (1:1) (T_1) recorded significantly higher number of branches plant^{-1} (3.66, 6.26 and 8.33 at 60, 120 DAS and at harvest, respectively) among different intercropping treatments. Significantly lower number of branches plant^{-1} (2.90, 4.21 and 7.16 at 60, 120 DAS and at harvest, respectively) was recorded with chilli (120 × 60 cm) + buckwheat (1:3) (T_3). The results demonstrate that intercropping chilli with buckwheat or green gram significantly reduces the number of branches per plant compared to sole chilli cultivation. This reduction is likely due to competition for resources such as light, nutrients and water, which is more pronounced in treatments with higher buckwheat densities. The sole chilli crop benefited from the absence of interspecific competition, allowing for greater branching and potentially, higher photosynthetic capacity and yield potential (Singh *et al*., 2018).

The temporal increase in branch numbers from 60 DAS to harvest across all treatments reflects the natural growth progression of chilli, with branching peaking at maturity. However, the relative differences between treatments remained consistent, indicating that early competition effects persisted throughout the crop cycle. These findings align with studies on intercropping systems, where resource competition from companion crops often reduces main crop vigor (Mpairwe *et al*., 2017). While buckwheat may provide benefits such as weed suppression, soil cover and nitrogen fixation. Farmers adopting such systems should consider lower intercropping densities or alternative companion crops like buckwheat or green gram to balance resource competition and crop productivity (Patel *et al*., 2021).

Conclusions

Chilli recorded higher plant height, Leaf area index, dry matter production and number of branches plant^{-1} in sole chilli. Among different intercropping systems chilli (90 × 90 cm) + buckwheat (1:1) recorded significantly higher plant height, Leaf area index, dry matter production and number of branches plant^{-1} of chilli.

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