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Performance of browntop millet under different intercropping systems

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Abstract
A field experiment was conducted at Main Agricultural Research Station, UAS, Dharwad during *kharif* season, 2021-22 to study the performance of intercropping of browntop millet with legumes. The experiment was laid out in randomized complete block design with thirteen treatments and three replications. Among thirteen treatments the browntop millet was intercropped with groundnut, soybean, green gram and black gram in 4:2 and 2:1 row ratio and remaining treatments were individual sole crops. Among the different treatments, the sole browntop millet was recorded significantly higher plant height, total dry matter production, number of tillers per meter row length at the all growth stages. Among the different intercropping systems, browntop millet + groundnut with 4:2 row ratio recorded significantly higher plant height, total dry matter production, number of tillers per meter row length at all growth stages. Sole browntop millet has recorded significantly higher effective tillers per meter row length (84.12), ear head length (15.20 cm), grain yield per ear head (5.19 g) and grain yield per meter row length (441.60 g). However, among the different intercropping systems, browntop millet + groundnut at 4:2 row proportion recorded significantly higher values of above mentioned yield parameters. Sole browntop millet has observed significantly higher grain and straw yield (973.61 and 2340.80 kg ha^{-1}, respectively), but among the different intercropping systems, 4:2 row proportion of browntop millet + groundnut recorded significantly higher grain yield (674.31 kg ha^{-1}) and straw yield (1580.30 kg ha^{-1}). In case of harvest index there was no significant differences observed between the different treatments.

Keywords: Browntop millet, economics, intercropping system, legumes, row ratio

Introduction
Small-seeded annual grasses collectively referred to as millets are produced as grain crops in arid areas of temperate, sub-tropical and tropical climates. Since major cereals are only cultivated on fertile soils with the advanced cultivation practices in-order to get the higher yields, the relevance of millets has been recognized more and more in recent years. Millets are noted for growing on low-fertile soils with readily available local inputs like farmyard manure, compost *etc*. In addition, they are resistant to insect and disease threats. Millets provide an incredible amount of nutrients. In terms of proteins, minerals (calcium and iron), vitamins, and fibre, each of the millets is three to five times more nutrient-dense than the frequently marketed rice and wheat. When compared to all other food crops, finger millet has the highest calcium content (344 mg per 100 g), followed by foxtail millet (12.9 mg per 100 g) and little millet (10.0 mg per 100 g). Minor millets are grown in India on an area of 4,58,350 ha, producing 3,70,810 tonnes per year with a productivity of 809 kg ha^{-1}. Minor millets are grown in Karnataka on an area of 49,000 ha, producing 37,490 tonnes and yielding 765 kg ha^{-1} (Anon., 2020) [1].
Due to insufficient and irregular rainfall, low soil fertility and unsuitable crop and cropping systems, the productivity of rainfed agro-ecosystems is low. The commercialization of novel crops with low water requirements is essential for achieving the sustainability in rainfed agriculture. These crops can also take the place of existing ones and cropping systems whose cultivation is unprofitable. Additionally, growing these crops in rainfed areas contributes to raising the standard of living for disadvantaged farmers and raising the quality of these crops. The efforts have largely been directed at increasing crop production on a single crop basis, with less focus on the related areas that affect crop growth, or the system as a whole. The research on cropping systems has revealed that intercropping with precise plant geometry

and choosing compatible crops with acceptable types are advantageous practices that helps to more effectively utilize the available soil nutrients and moisture. Intercropping is a potentially beneficial system, shows substantial yield advantage over so1e cropping and reduces risk. It can increase the production and productivity through the better utilization of available land resources. Intercropping of millets with pulses such as pigeonpea, green gram, black gram *etc*., could be a viable risk minimizing agronomic means of sustainable venture.

Materials and Methods

The field experiment was conducted on medium deep black soil at Main Agricultural Research Station, UAS, Dharwad (located at 15º 26¹ N latitude, 75º 07¹ E longitude and an altitude of 678 m above the mean sea level.). The total rainfall received during 2021 was 1052.30 mm. Experiment was comprised with 13 treatments under sole and intercropping systems. The experiment was laid out in randomized complete block design and replicated thrice. The land was ploughed twice with tractor drawn mould board plough in order to bring the land to the optimum tilth. The soil of experimental plot was medium deep black soil with pH 7.74, available organic carbon 0.49 percent, available N, P and K were 290.80, 28.30 and 331.40 kg ha^{-1}, respectively.

Sowing of browntop millet and different legumes was carried out on 26th July 2021. Seeds of browntop millet (Local cultivar), groundnut (DH-256), soybean (DSb-21), green gram (IPM-2-14) and black gram (DU-1) were sown by using khera method (dropping of seeds through hands in furrow behind the plough) with seed rate of 5-7 kg ha^{-1} (Browntop millet), 100–110 kg ha^{-1} (Groundnut), 62 kg ha^{-1} (Soybean), 12-15 kg ha^{-1} (Green gram), 15-18 kg ha^{-1} (Black gram). Weeds were controlled through one hoeing at 30 days after sowing and one manual weeding. The recommended dose of fertilizer for browntop millet (30:15:15 kg ha^{-1}), groundnut (18:46:25 kg ha^{-1}), soybean (40:80:25 kg ha^{-1}), green gram (25:50:0 kg ha^{-1}) and black gram (25:50:0 kg ha^{-1}) in the form DAP, urea and MOP was applied at the time of sowing. In case of intercropping treatments fertilizers were applied based on the population level. The seed treatment with *Rhizobium strains* (50 g kg^{-1} seeds) was done for the seeds of groundnut, soybean, green gram and black gram, browntop millet was treated with *Azospirullum* (50 g kg^{-1} seeds). Five plants were tagged randomly from each plot for recording various yield attributes at harvest stage. Standard procedures were used to measure the yield of both main and intercrops. Significance and non-significance difference between treatments was derived through Duncan's Multiple Range Test (DMRT) using Online Statistical Analysis Tool (OPSTAT). The yield was computed for browntop millet equivalent yield (BMEY), land equivalent ratio (LER), gross and net returns as well as B:C ratio to assess the system productivity.

Results and Discussion

Effect of intercropping system on growth attributes

It was observed that when two or more crops are grown together as intercrops, their growth attributes are generally reduced in intercropping system compared to their growth obtained under sole cropping systems. The data (Table 1) revealed that sole browntop millet was recorded higher plant height at all the growth stages, but the plant height at 30 days was not differed significantly because this stage coincides with the germination and establishment of crop. During the time of germination, the nutrient demand of crop is met with the reserved food in the endosperm of the seed. Further, the nutrient must undergo mineralization to become available besides proliferation of root system inorder to absorb the nutrients. At 60 DAS, browntop millet + groundnut with 4:2 row ratio (60.40 cm) and 2:1 row ratio (60.20 cm), browntop millet + soybean with 4:2 row ratio (59.00 cm) and 2:1 row ratio (58.60 cm) and browntop millet + green gram with 4:2 row ratio (57.20 cm) were showed on par results when compared to the sole browntop millet (64.20 cm) which recorded significantly higher plant height. The variation in plant height at harvest stage was not statistically significant, among the different intercropping system browntop millet + groundnut with 4:2 row ratio was recorded numerically higher values (27.33 cm). This was mainly due to the competition among the main and intercrops for nutrients, space, light etc.

Significantly higher total dry matter production per meter row length was recorded in sole browntop millet (523.50 g) at 60 DAS when compared to other treatments. However, it was on par with bowntop millet + groundnut (489.94 g) with 4:2 row ratio and browntop + groundnut (475.60 g) with 2:1 row ratio. Significantly lower dry matter production per meter row length was recorded in browntop millet + black gram (396.20 g) at 2:1 row ratio compared to other intercropping systems. At harvest stage also, sole browntop millet was recorded significantly higher values (1749.80 g) and it was on par with 4:2 row proportion of browntop millet + groundnut (1606.10 g) and browntop millet + soybean (1567.62 g), and 2:1 row proportion of browntop millet + groundnut (1586.85 g) and browntop millet + soybean (1548.70 g). There was no significant differences were found among the treatments at 30 DAS stage (Table 1). The same trend was followed with respect to number of tillers per meter row length. However, at 60 DAS, sole browntop millet was recorded significantly higher tillers per meter row length (118.30) and it was on par with browntop millet + groundnut (106.70) at 4:2 ratio and browntop millet + groundnut (105.60) at 2:1 ratio. At harvest, sole browntop millet was recorded significantly higher tillers per meter row length (136.00). However, it was on par with 4:2 and 2:1 row proportion of browntop millet + groundnut (130.70 and 128.00, respectively) and browntop millet + soybean (126.00 and 123.70, respectively). Significantly lower number of tillers per meter row length was observed in browntop millet + black gram (111.00) at 2:1 row proportion (Table 1). It was due to less competition from competing crops, better resource utilizations and the benefit of legumes on millet contributed to higher dry matter production and number of tillers. The similar results were reported by Sharma and Gupta (2001) [7], they reported that in association with cowpea and mungbean, pearl millet plants grow taller and dry matter accumulation was slightly higher in the pearl millet + mungbean combination. According to Yakadri and Gautham (2001) [11], the intercropping system of groundnut and pearl millet in 2:4 ratio had a significant impact on the higher dry matter production by pearl millet than 2:1 and 1:2 row ratios.

Effect of intercropping system on yield and yield attributes

Significantly higher number of effective tillers per meter row length was observed in sole browntop millet (84.12) as compared to other treatments (Table 2). However, it was

found on par with browntop millet + groundnut (77.00) in 4:2 row ratio and browntop millet + groundnut (75.55) in 2:1 row ratio. In case of ear head length sole browntop millet was recorded significantly higher ear head length (15.20 cm). However, it was on par with all other treatments except browntop millet + blackgram in 4:2 row ratio, which was recorded significantly lower ear head length (13.10 cm). No significant difference was observed in case of thousand grain weight (Table 2). However, among different cropping systems sole browntop millet was recorded numerically higher thousand grain weight (3.60 g). Sole browntop millet was recorded significantly higher grain yield per ear head (5.19 g). However, among the different intercropping systems, browntop millet + groundnut in 4:2 row proportion recorded significantly higher grain yield per ear head (4.25 g) (Table 2). Significantly higher grain yield per meter row length was recorded in sole browntop millet (441.60 g). However, among the different intercropping systems browntop millet + groundnut (327.40 g) in 4:2 row ratio was recorded significantly higher grain yield per meter row length (Table 2). The higher yield attributes in browntop millet grown alone as compared to other intercropping treatments were caused by variations in the translocation of photosynthates from source to sink. As reported by Bar and Gautham (1991) [2]. pearl millet grown with either groundnut, castor or soybean in intercropping systems, sole pearl millet shows higher yield characters and in intercropping system pearl millet attained statistically the same yield characters, In comparison to other cropping systems, Maitra *et al.* (2000) [4] found that finger millet + pigeonpea in 4:2 intercropping produced higher fingers per ear. Triveni *et al.* (2017) [10], noticed that sole pearl millet recorded significantly higher grain weight per ear head, length of ear head and thousand grain weight (14.3 g, 25.4 cm and 8.5 g, respectively), but among the different intercropping systems it was observed that all the yield attributes were higher in pearl millet + cowpea at 2:2 row proportion (13.1 g, 25.2 cm and 8.4 g, respectively), while these parameters were lowest in pearl millet + groundnut at 1:1 row proportion (11.7 g, 23.3 cm and 8.3 g, respectively).

Browntop millet yield varied significantly between sole and intercropping treatments as compared to intercropping system treatments, the sole browntop millet was recorded significantly higher grain yield (973.61 kg ha^{-1}). The percent yield increased with sole browntop millet was to the tune of 30, 33, 33 and 34%, respectively over 4:2 row ratio of browntop millet + groundnut, browntop millet + soybean, browntop millet + green gram, browntop millet + black gram. Whereas, 2:1 row ratio did not show much differences in grain yield (Table 2).

Among different intercropping systems, 4:2 row ratio of browntop millet + groundnut was recorded significantly higher grain yield (674.31 kg ha^{-1}) and the percent yield increased was 4.6, 4.7 and 4.9 percent higher as compared to 4:2 row ratio of browntop millet + soybean, browntop millet + green gram and browntop millet + black gram, respectively and 1.3, 4.7, 5.4 and 5.5 percent higher compared to 2:1 row ratio of browntop millet + groundnut, browntop millet + soybean, browntop millet + green gram and browntop millet + black gram, respectively (Table 2). The sole browntop millet produced higher grain yield, over the intercropping treatments, which can be attributed to 100 percent plant population and absence of competition from intercrops. Apart from above, the yield increase was due to higher grain weight per panicle, grain weight per meter row length and number of panicles per meter row length of sole browntop millet. Similar results have been reported by Sahu and Patro (1993) [6], who found that when little millet was intercropped with green gram in a 4:1 row ratio and black gram in a 4:1 row ratio, as opposed to little millet grown as a sole crop, a higher grain yield was obtained in sole little millet (654 kg ha^{-1}). According to Mitra *et al.* (2000) [4], finger millet grown as a single crop produced higher grain yield than finger millet grown in an intercropping system with green gram and soybean.

Among the different treatments, sole browntop millet produced significantly higher straw yield (2340.80 kg ha^{-1}) than the other treatments, the percent straw yield increase with sole browntop millet was to the extent of 32, 35, 36 and 37 percent when compared to 4:2 row ratio of browntop millet + groundnut, browntop millet + soybean, browntop millet + green gram and browntop millet + black gram respectively and 35, 38, 38 and 39 percent when compared to 2:1 row ratio of browntop millet + groundnut, browntop millet + soybean, browntop millet + green gram and browntop millet + black gram, respectively. Among the different intercropping systems browntop millet + groundnut in 4:2 row proportion was recorded higher straw yield (1580.30 kg ha^{-1}) and the percent straw yield was increased to the extent of 4.7, 5.3 and 7.2 as compared to 4:2 row ratio of browntop millet + soybean, browntop millet + green gram, browntop millet + black gram, respectively (Table 2). Higher dry matter production and population could be the causes of this increase in straw yield. Similar results were noted by Shivakumar and Yadahalli (1995) [8], who found that finger millet grown as a single crop produced more straw yield than finger millet intercropped with 4:2 row ratios of fieldbean with finger millet, little millet, and foxtail millet recorded higher straw yield (14.0%, 2.4%, and 10.7% respectively) over 2:1 row ratio due to more space being available (120 cm vs. 60 cm between two sets in 2:1 row ratio), which resulted in better light availability, better resource utilization and less inter and intra-species competition. According to Prasannakumar *et al.* (2009) [5], 6:2 row ratio of pigeonpea + little millet produced higher straw yield than an intercropping system with 3:1 ratio. In case of harvest index there was no significant differences observed between the different treatments (Table 2). However, sole browntop millet recorded numerically higher harvest index (32.81 %).

Effect of intercropping system on economics

Sole groundnut recorded significantly higher gross returns (₹ 1,13,438 ha^{-1}) followed by sole soybean (₹ 1,01,189 ha^{-1}). However, among the different intercropping systems, browntop millet + groundnut (₹ 72,397 ha^{-1}) at 4:2 row proportion recorded numerically higher gross returns (Table 3). Similar trend was noticed with net returns whereas, sole groundnut was recorded significantly higher net returns (₹ 72,934 ha^{-1}), followed by sole soybean (₹ 62,282 ha^{-1}). Higher groundnut and soybean yield as well as higher market prices for these two crops were the main reasons for the higher gross returns and net returns. However, among the different intercropping systems numerically higher net returns was recorded with browntop millet + ground (₹ 37,971 ha^{-1}) at 4:2 row proportion (Table 3). This was mainly because of low market price of browntop millet and low productivity. Similarly Prasannakumar *et al.* (2009) [5] reported that intercropping of pigeonpea and little millet in a

horsegram sequence (6:2 row ratio) resulted in significantly higher gross returns than sole cropping. According to Kumaraswamy (1981) [3], finger millet + soybean in paired rows was recorded the highest net returns when compared to finger millet as a sole crop. Significantly higher B:C ratio recorded in sole groundnut (2.80), followed by sole soybean (2.60). However, among the different intercropping systems, browntop millet + groundnut (2.10) at 4:2 row proportion recorded numerically higher B:C ratio (Table 3). These findings are in line with those made by Singh and Arya (1999) [9], who found that intercropping of finger millet with soybean at 4:2 row proportion increased the net returns and B:C ratio than sole finger millet.

Table 1: Growth parameters of browntop millet as influenced by intercropping with legumes at different growth stages

Tr. No.	Treatments	Plant height (cm)			Total dry matter production (g meter row length^{-1})			Number of tillers (meter row length^{-1})		
		30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	Browntop millet + groundnut (4:2)	27.33^{a}	60.40^{ab}	83.60^{a}	42.60^{a}	489.94^{ab}	1606.10^{ab}	40.65^{a}	106.70^{ab}	130.70^{ab}
T_2	Browntop millet + soybean (4:2)	26.53^{a}	59.00^{ab}	81.60^{a}	42.01^{a}	458.20^{b-d}	1567.62^{ab}	39.80^{a}	102.72^{b}	126.0^{a-d}
T_3	Browntop millet + green gram (4:2)	25.60^{a}	57.20^{ab}	80.55^{a}	40.80^{a}	425.32^{cd}	1524.50^{b}	39.22^{a}	100.01^{b}	120.00^{b-d}
T_4	Browntop millet + black gram (4:2)	25.22^{a}	56.80^{b}	80.36^{a}	40.50^{a}	420.15^{cd}	1487.60^{b}	38.80^{a}	99.08^{b}	118.30^{b-d}
T_5	Browntop millet + groundnut (2:1)	27.13^{a}	60.20^{ab}	82.90^{a}	42.32^{a}	475.60^{a-c}	1586.85^{ab}	40.30^{a}	105.60^{ab}	128.00^{a-c}
T_6	Browntop millet + soybean (2:1)	26.03^{a}	58.60^{ab}	81.20^{a}	41.60^{a}	446.25^{b-d}	1548.70^{ab}	39.50^{a}	101.30^{b}	123.70^{a-d}
T_7	Browntop millet + green gram (2:1)	25.07^{a}	56.00^{b}	80.20^{a}	39.88^{a}	405.62^{d}	1472.70^{b}	38.55^{a}	97.70^{b}	112.70^{cd}
T_8	Browntop millet + black gram (2:1)	25.03^{a}	55.40^{b}	79.80^{a}	39.60^{a}	396.20^{d}	1430.10^{b}	38.00^{a}	96.00^{b}	111.00^{d}
T_{13}	Sole browntop millet	29.70^{a}	64.20^{a}	85.46^{a}	45.20^{a}	523.50^{a}	1749.80^{a}	42.32^{a}	118.30^{a}	136.00^{a}
S.Em.±		1.53	2.05	2.86	1.70	18.40	63.60	1.60	4.00	4.60

Note: means followed by the same letter(s) within the column did not differ significantly by DMRT (p= 0.05) DAS- Days after sowing

Table 2: Yield and yield components of browntop millet as influenced by intercropping with legumes

Tr. No.	Treatments	Effective tillers meter row length^{-1}	Earhead length (cm)	Thousand grains weight (g)	Grain yield ear head^{-1} (g)	Grain yield meter row length^{-1} (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI (%)
T_1	Browntop millet + groundnut (4:2)	77.00^{ab}	15.00^{ab}	3.53^{a}	4.25^{b}	327.40^{b}	674.31^{b}	1580.30^{b}	30.01^{a}
T_2	Browntop millet + soybean (4:2)	73.45^{bc}	14.30^{ab}	3.40^{a}	3.93^{b-d}	286.20^{cd}	642.82^{b}	1505.30^{b}	29.91^{a}
T_3	Browntop millet + green gram (4:2)	68.25^{b-d}	13.70^{ab}	3.20^{a}	3.74^{b-d}	254.10^{d-f}	642.36^{b}	1496.93^{b}	30.13^{a}
T_4	Browntop millet + black gram (4:2)	65.23^{cd}	13.10^{b}	3.17^{a}	3.60^{cd}	234.70^{e-g}	640.74^{b}	1465.30^{b}	30.39^{a}
T_5	Browntop millet + groundnut (2:1)	75.55^{ab}	14.70^{ab}	3.50^{a}	4.08^{bc}	306.70^{bc}	665.51^{b}	1515.22^{b}	30.56^{a}
T_6	Browntop millet + soybean (2:1)	70.36^{b-d}	14.00^{ab}	3.47^{a}	3.83^{b-d}	268.20^{de}	642.36^{b}	1449.30^{b}	30.82^{a}
T_7	Browntop millet + green gram (2:1)	63.32^{d}	13.70^{ab}	3.03^{a}	3.51^{d}	222.30^{fg}	637.64^{b}	1449.80^{b}	30.80^{a}
T_8	Browntop millet + black gram (2:1)	61.43^{d}	13.90^{ab}	3.27^{a}	3.44^{d}	209.80^{g}	637.04^{b}	1421.88^{b}	31.00^{a}
T_{13}	Sole browntop millet	84.12^{a}	15.20^{a}	3.60^{a}	5.19^{a}	441.60^{a}	973.61^{a}	2340.80^{a}	32.81^{a}
S.Em.±		2.90	0.58	0.14	0.16	11.53	27.72	64.05	1.26

Note: means followed by the same letter(s) within the column did not differ significantly by DMRT (p= 0.05)

Table 3: Economics of browntop millet and legumes under sole and intercropping systems

Tr. No.	Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	Browntop millet + groundnut (4:2)	34426	72397^{b}	37971^{b}	2.10^{b}
T_2	Browntop millet + soybean (4:2)	34516	70455^{b}	35939^{bc}	2.04^{b}
T_3	Browntop millet + green gram (4:2)	32674	53186^{c}	20512^{c}	1.63^{c}
T_4	Browntop millet + black gram (4:2)	32648	54617^{c}	21969^{bc}	1.67^{c}
T_5	Browntop millet + groundnut (2:1)	34398	71555^{b}	37157^{b}	2.08^{b}
T_6	Browntop millet + soybean (2:1)	34500	70360^{b}	35859^{bc}	2.04^{b}
T_7	Browntop millet + green gram (2:1)	32670	52222^{c}	19552^{c}	1.60^{c}
T_8	Browntop millet + black gram (2:1)	32643	52985^{c}	20341^{c}	1.62^{c}
T_9	Sole groundnut	40504	113438^{a}	72934^{a}	2.80^{a}
T_{10}	Sole soybean	38907	101189^{a}	62282^{a}	2.60^{a}
T_{11}	Sole green gram	34276	62381^{bc}	28105^{bc}	1.82^{bc}
T_{12}	Sole black gram	34178	64199^{bc}	30020^{bc}	1.88^{bc}
T_{13}	Sole browntop millet	29005	31210^{d}	2205^{s}	1.08^{d}
S.Em.±		-	4621	4984	0.088

Note: means followed by the same letter(s) within the column did not differ significantly by DMRT (p= 0.05)

Conclusion

Based on the results, it may summarized that sole browntop millet recorded significantly higher growth, yield attributes and economics as compared to all the intercropping systems. However, the results indicated that among the different intercropping systems browntop millet + groundnut at 4:2 row ratio recorded significantly higher growth, yield attributes and economics. Among the two different row proportions browntop millet performed better in 4:2 row proportion than 2:1 row proportion with all the legumes. Therefore, it was concluded that browntop millet + legume (4:2) intercropping system is found to be suitable for northern dry zone of Karnataka under rainfed condition.

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