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Research Article

AGRONOMIC INVESTIGATIONS ON FINGER MILLET + *AKKADI* SYSTEM UNDER DRYLAND SITUATION

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Abstract: Field investigation was carried at All India Co-ordinated Research Project for Dryland Agriculture, UAS, GKVK, Bengaluru during *kharif* 2015 on finger millet based *Akkadi* intercropping system under Dryland situation in *alfisol*. The experiment consisting of two factors *i.e*., factor A (4 crop mixtures) and factor B (2 row proportions) with eight treatment combinations. Among different crop mixtures and row proportions, intercropping finger millet with *Akkadi* 8 crops consisting in 8:1 row proportion recorded higher finger millet grain (3319 kg ha^{-1}), straw yield (5267 kg ha^{-1}). Among different crop mixtures finger millet with 8 *Akkadi* crops recorded higher finger millet equivalent yield (3893 kg ha^{-1}), rain water use efficiency (7.00 kg ha-mm^{-1}), net returns (Rs. 57499 ha^{-1}) and benefit: cost ratio (3.0) compared to other crop mixtures. Among the *Akkadi* crops, higher yield of fodder sorghum (982 kg ha-$^{-1}$) was recorded in intercropping finger millet with 7 *Akkadi* crops under 8:2 row proportion with conservation furrow compared other treatment combinations.

Keywords: *Akkadi, Intercropping, Dryspell, Conservation furrow, Rain Water Use Efficiency*

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Introduction

Indian agriculture is dominated with rainfed farming. Green revolution made the country self-sufficient in food but it surpassed the dryland areas which constitute 60 percent in the cultivated area and have become the hot spots of poverty, hunger, malnutrition, water scarcity and land degradation. Out of 141 m ha of net sown area in the country, 80 m ha is rainfed. Rainfed agriculture contributes 40% of food grain production. Despite considerable progress in irrigation development over the V year Plan, 85% of coarse cereals, 83% in pulses, 42% in rice, 70% in oilseeds and 65% in cotton are still cultivated as rainfed [3]. Nearly 75% of the total cultivated area in Karnataka is under dryland ecosystem which is contributing nearly 55% of total food grain production [1]. In view of the geographical position as an upper riparian state, scope for increasing the irrigation potential is limited. Analysis of rainfall pattern of the state indicates that 3 to 4 years in every decade face severe drought, sometimes consecutively also. A vast majority of dryland area receive an annual average rainfall of 450 to 700 mm, which is highly erratic and unevenly distributed during the cropping seasons. Crop diversity is the major factor for sustainability of farmers in this fragile eco-system. Traditionally, farmers are resorting for *Akkadi* based intercropping/ mixed cropping systems to meet fodder, vegetable, food grains and oilseeds. *Akkadi* is a system in which mixture of 3-9 different crops *viz*., cereals (foxtail millet and sorghum), pulses (pigeonpea, cowpea, French bean and field bean), oilseeds (Niger, mustard and castor) in indefinite row proportions with the main crop. In finger millet and groundnut based systems one row of *Akkadi* crops with 8-15 rows of main crop are the commonly followed practices [6]. Although historically the crop diversity was maintained with local varieties of the selected crops in *Akkadi* system, which are compatible with each other, modern sustainable cropping systems envisaged high yielding / improved varieties with specialized intercropping considering the system productivity, economics, soil health and practicality in implementation and management. Further due to climate change, there has been a change in number of rainy days and increase in rainfall intensity leading to undesirable dimension to the sustainability on the rainfed ecosystem. Hence, crop diversification needs emphasis with the objective of subsistence and sustainable to the changed climatic situations. Identification of appropriate blend of crops, their proportion and method of establishment needs thorough investigation. Keeping this in view, field investigation was initiated to standardize the crop geometry and establishment for *Akkadi* system under finger millet-based intercropping and to assess impact on economics.

Material and methods

Field investigation was conducted at All India Co-ordinated Research Project for Dryland Agriculture, UAS, GKVK, Bengaluru during *kharif* 2015. The land is situated at 77° 35' E longitude and 12° 35' N latitude at an altitude of 930 m above mean sea level. The soil is predominantly belonging to *Alfisol*s, sandy loam in texture, > 2 m deep, having field capacity of 31.6 % with pH 5.30 and 0.50 % organic carbon. The available N, P and K status was 170.5, 98.9 and 90.7 kg ha^{-1}, respectively. During the experimental season, total of 558.4 mm rainfall was received in 32 rainy days against normal rainfall of 514.2 mm. Highest monthly rainfall during crop season was 254.2 mm in the month of September. The highest amount of rainfall was received on 7th September (92.4 mm). During cropping season, there were two dry spells; 25 days from 8th October to 1st November and no rains from 4th December onwards. The first dryspell coincided with flowering of most of the crops and thus resulted in reduced yield attributes. Later from November 2nd there was drizzling till November 24th with cloudy weather coinciding with ripening stage of most of crops. Cloudy weather with intermittent rain at maturity stage of crop led to grain shattering. Overall, the rainfall behaviour was erratic during the crop season and resulted in yield loss. The weekly mean maximum temperature ranged from 23.2° to 30.3°C with an average of 28°C and daily mean minimum temperature ranged from 16.8° to 21.9°C with an average of 18.9°C during crop period. The weekly mean maximum relative humidity during experiment ranged from 87 to 97 percent with an average of 91.4 percent and daily mean minimum relative humidity ranged from 46 to 76 percent with an average of 54.4 percent. The daily mean sun-shine duration varied from 0.1 to 9.3 hrs (average 5.3 hrs).

Table-1 *Standard metrological week-wise weather data during experimentation during 2015*

Metrological Standard week	Rainfall (mm)	MAX (°C)	MIN (°C)	SSH (hrs)	EVP (mm)	RH (%)
33 (Aug. 13-Aug.19)	11.8	29.6	20.1	4.6	3.7	70.0
34 (Aug. 20-Aug.26)	28.2	29.7	19.5	6.7	3.5	70.5
35 (Aug. 27-Sep.02)	4.0	29	19.4	4.1	4.1	72.0
36 (Sep.03-Sep.09)	134.8	29.7	19.5	6	3.4	71.5
37 (Sep.10-Sep. 16)	6.2	27.1	18.9	3.8	3.8	73.0
38 (Sep.17-Sep. 23)	3.8	28.6	19	5.3	4.3	72.5
39 (Sep.24-Sep. 30)	109.4	29	19.4	5.9	4.1	73.0
40 (Oct.01-Oct. 07)	80.8	27.9	20	2.5	3.3	74.5
41 (Oct.08-Oct. 14)	-	29.1	19.2	5.2	4.1	70.5
42 (Oct.15-Oct. 21)	-	30.3	19.1	9.2	5.3	67.5
43 (Oct.22-Oct. 28)	-	29.5	17.9	8.8	5.2	68.5
44 (Oct.29-Nov. 04)	50.0	28.5	19	4.9	4.2	67.0
45 (Nov.05-Nov.11)	67.8	25.5	18.3	4.8	3.3	79.0
46 (Nov.12-Nov.18)	34.6	23.2	16.9	0.1	1.9	85.0
47 (Nov.19-Nov. 25)	22.2	24.5	18.4	2.2	2.4	79.5
48 (Nov.26-Dec.02)	3.4	26.3	16.8	7.5	2.9	77.5
49 (Dec.03-Dec.09)	1.4	26.2	16.9	2.8	2.8	71.8
50 (Dec.10-Dec.16)	-	28.9	18.6	6.1	3.4	72.8
51 (Dec.17-Dec.23)	-	28.7	21.9	9.3	3.7	69.1
Total / Mean	558.4	28.0	18.9	5.3	3.7	72.9

MAX: Maximum temperature, MIN: Minimum temperature, SSH: Sunshine hours, EVP: Evaporation, RH: Relative Humidity

Table-2 *Effect of finger millet based akkadi system on yield and economics of finger millet*

Treatments	Finger millet grain yield (kg ha^{-1})	Finger millet straw yield (kg ha^{-1})	Finger millet equivalent yield (kg ha^{-1})	RWUE (kg ha-mm^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C ratio
T_1-C_1R_1	2970	4718	3680	6.57	80955	52949	2.89
T_2-C_1R_2	2925	4674	3571	6.38	78555	50359	2.79
T_3-C_2R_1	3319	5267	3921	7.00	86266	58210	3.07
T_4-C_2R_2	3117	4937	3865	6.90	85035	56789	3.01
T_5-C_3R_1	3170	5113	3808	6.80	83774	55668	2.98
T_6-C_3R_2	3010	4937	3746	6.69	82402	54106	2.91
T_7-C_4R_1	3239	5267	3863	6.90	84987	56831	3.02
T_8-C_4R_2	3018	4839	3786	6.76	83286	54940	2.94

Table-3 *Effect of different crop mixtures and row proportions on yield and economics of finger millet*

Treatments	Finger millet Grain yield	Finger millet Straw yield	Finger millet equivalent yield	RWUE (kg ha-mm^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C ratio
	(kg ha^{-1})						
Crop mixture (C)							
C_1 (7 crops)	2948	4696	3625	6.49	79755	51654	2.84
C_2 (8 crops)	3218	5102	3893	6.97	85650	57499	3.04
C_3 (9 crops)	3090	5025	3777	6.76	83088	54887	2.95
C_4 (10 crops)	3129	5053	3824	6.85	84136	55885	2.98
Row proportions (R)							
R_1 (8:1)	3174	5091	3818	6.84	83996	55915	2.99
R_2 (8:2)	3018	4847	3742	6.70	82319	54048	2.91

Table-4 *Effect of finger millet based akkadi system on yield of akkadi crops*

Treatments	*Akkadi* crops yield (kg ha^{-1})									
	Fodder sorghum	Castor	Pigeon pea	Field bean	Cow Pea	Mustard	Niger	French bean	Ash gourd	Ridge gourd
T_1-C_1R_1	862.8	79.0	51.0	16.4	15.3	1.8	25.7			
T_2-C_1R_2	982.0	90.5	60.2	20.8	21.2	2.4	29.8			
T_3-C_2R_1	810.8	80.6	49.0	15.2	16.3	1.7	22.6	63.1		
T_4-C_2R_2	938.1	93.6	63.3	22.5	22.3	2.7	28.7	74.4		
T_5-C_3R_1	850.0	83.0	53.0	16.7	16.5	1.8	25.8	62.8	1.2	
T_6-C_3R_2	964.2	93.0	60.0	22.0	22.1	2.3	29.8	75.0	2.3	
T_7-C_4R_1	850.0	83.1	50.0	15.5	15.1	1.9	26.0	63.8	1.3	3.2
T_8-C_4R_2	977.5	99.0	63.0	22.1	22	2.5	31.6	74.1	2.0	6.0

The daily mean variation of evaporation ranged from 1.9 to 5.3 mm with an average of 3.7 mm during crop period [Table-1]. Factorial experiment consisting two factors *i.e.*, Factor A (4 different crop mixture) and Factor B (2 row proportions) with eight different treatment combinations was taken up. The trial was unreplicated and conducted on gross plot size of 10 m × 9.9 m and net plot size was 9.8 m × 9.3 m. Factor A: different crop mixture *viz.*, C1: 7 Crops (fodder sorghum, castor, pigeonpea, field bean, cowpea, mustard and niger; C2: 8 Crops (fodder sorghum, castor, pigeonpea, field bean, cowpea, mustard, niger and french bean); C3: 9 Crops (fodder sorghum, castor, pigeonpea, field bean, cowpea, mustard, niger, french bean and ash gourd) and C4: 10 Crops (fodder sorghum, castor, pigeonpea, field bean, cowpea, mustard, niger, french bean, ash gourd and ridge gourd)} and Factor B: row proportions *viz.*, R1: 8:1 and R2: 8:2 with conservation furrow). Medium duration finger millet variety (GPU-28) and drought resistant improved varieties of *Akkadi* crops were sown. Recommended dose fertilizer for finger millet crop (50: 40: 37.5 kg N, P_2O_5 and K_2O ha^{-1}) was applied to all the treatments in the form of urea, DAP, muriate of potash, respectively. 50 % of N and full dose of P_2O and K_2O were applied basally at the time of sowing; remaining 50% was nitrogen top dressed at active tillering stage.

Table-5 *Effect of different crop mixtures and row proportions on yield of akkadi crops*

Treatments	*Akkadi* crops yield (kg ha^{-1})									
	Fodder sorghum	Castor	Pigeon pea	Field bean	Cow Pea	Mustard	Niger	French bean	Ash gourd	Ridge gourd
Crop mixture (C)										
C_1 (7 crops)	922.4	84.8	55.6	18.6	18.3	2.1	27.8			
C_2 (8 crops)	874.5	87.1	56.2	18.9	19.3	2.2	25.7	68.8		
C_3 (9 crops)	907.1	88.0	56.5	19.4	19.3	2.0	27.8	68.9	1.8	
C_4 (10 crops)	913.8	91.1	56.5	18.8	18.6	2.2	28.8	69.0	1.7	4.6
Row proportions (R)										
R_1 (8:1)	843.4	81.4	50.8	16.0	15.8	1.8	25.0	63.2	1.3	3.2
R_2 (8:2)	965.4	94.0	61.6	21.9	21.9	2.5	30.0	74.5	2.2	6.0

Table-6 Effect of finger millet based *akkadi* system on finger millet equivalent yield of *akkadi* crops

Treatments	*Akkadi* crops yield (kg ha^{-1})									
	Fodder sorghum	Castor	Pigeon pea	Field bean	Cow Pea	Mustard	Niger	French bean	Ash gourd	Ridge gourd
T_1-C_1R_1	39.2	143.6	231.8	41.0	34.8	2.0	70.1			
T_2-C_1R_2	44.6	164.5	273.6	52.0	48.2	2.7	81.3			
T_3-C_2R_1	36.9	146.5	222.7	38.0	37.0	1.9	61.6	86.0		
T_4-C_2R_2	42.6	170.2	287.7	56.3	50.7	3.1	78.3	101.5		
T_5-C_3R_1	38.6	150.9	240.9	41.8	37.5	2.0	70.4	85.6	0.8	
T_6-C_3R_2	43.8	169.1	272.7	55.0	50.2	2.6	81.3	102.3	1.6	
T_7-C_4R_1	38.6	151.1	227.3	38.8	34.3	2.2	70.9	87.0	0.9	3.6
T_8-C_4R_2	44.4	180.0	286.4	55.3	50.0	2.8	86.2	101.0	1.4	6.8

All the crop components were sown on 13th August and harvesting was done as and when crops were ready to harvest either for vegetable or grain purpose. The yield of intercrops was converted into finger millet grain equivalent yield (FGEY) taking into account the yield and prevailing price of the produce. The economics of system was worked out considering the prevailing cost of inputs and price of the produce. The total rainfall received during the crop growth period was used to work out the rain water use efficiency (RWUE) as kg of grain produced per ha mm of rain water (kg ha- mm^{-1}).

Results and discussion

The data indicated that, among the different crop mixtures and row proportions, intercropping finger millet with 8 crops under 8:1 row proportion recorded higher finger millet grain (3319 kg ha^{-1}) and straw yield (5267 kg ha^{-1}) followed by finger millet with 10 crops under 8:1 row proportion (3239 kg ha^{-1} and 5267 kg ha^{-1} respectively) compared to 8:2 row proportion with conservation furrow. The higher finger millet plant population under 8:1 row proportion resulted in higher finger millet grain and straw yield [4]. Higher finger millet equivalent yield (3921 kg ha^{-1}) and rain water use efficiency (7.00 kg ha-mm^{-1}) was recorded in finger millet with 8 crops under 8:1 row proportion followed by finger millet with 8 crops under 8:2 row proportion (3865 kg ha^{-1} and 6.90 kg ha-mm^{-1}, respectively). With regard to economics, growing finger millet with 8 crops under 8:1 ratio recorded higher net returns (Rs. 58210 ha^{-1}) and benefit: cost ratio (3.07) followed by growing finger millet with 10 crops under 8:1 ratio [Table-2]. Among different crop mixtures finger millet with 8 crops recorded higher finger millet equivalent yield (3893 kg ha^{-1}), rain water use efficiency (6.97 kg ha-mm^{-1}), net returns (Rs. 57499 ha^{-1}) and benefit: cost ratio (3.04) compared to other crop mixtures, similar results was recorded by [6] and under different row proportions 8:1 row proportion recorded higher finger millet equivalent yield (3818 kg ha^{-1}), rain water use efficiency (6.84 kg ha-mm^{-1}), net returns (Rs. 55915 ha^{-1}) and benefit: cost ratio (2.99) due to higher finger millet yield compared to 8:2 row proportion with conservation furrow [Table-3]. The performance of *Akkadi* crops was poor due to the erratic rainfall distribution and continuous drizzling/ cloudy weather during maturity phase. This might have masked the influence of moisture conservation furrow in the present experiment especially for finger millet equivalent yield in 8:2 row proportions. Similar results were reported in [7]. The increased yield and economics were associated with increased soil profile moisture and also, intercropping of compatible crops benefit mutually in improving system productivity and returns. Higher yield of fodder sorghum (982 kg ha^{-1}) was recorded in intercropping finger millet with 7 crops under 8:2 row proportion with conservation furrow compared other treatment combinations. Species yielding ability and performance depends on individual, mutual competition and resource utilization [5]. Finger millet with 10 crops under 8:2 row proportion with conservation furrow recorded higher castor, niger and ridge gourd yield (99.0, 31.6 and 6.0 kg ha^{-1}, respectively) compared to other treatments. Higher pigeonpea, field bean, cowpea and mustard yield (63.3, 22.5, 22.3 and 2.7 kg ha^{-1}, respectively) was recorded in intercropping finger millet with 8 crops under 8:2 row proportion with conservation furrow. Comparatively higher yield of french bean (75 kg ha^{-1}) and ash gourd (2.3 kg ha^{-1}) was recorded with intercropping finger millet with 9 crops under 8:2 row proportion with conservation furrow [Table-4]. Among the *Akkadi* crop, higher finger millet equivalent yield (287.7 kg ha^{-1}) recorded in pigeonpea with 8:2 row proportion followed by 10:2 row proportion (286.4 kg ha^{-1}) [Table-6]. These results are in confirmation with the findings of [2].

Conclusion

Among different crop mixtures finger millet with 8 crops recorded higher finger millet equivalent yield (3893 kg ha^{-1}), rain water use efficiency (6.97 kg ha-mm^{-1}), net returns (Rs. 57499 ha^{-1}) and benefit: cost ratio (3.04) compared to other crop mixtures

Application of research: In finger millet + *Akkadi* system, intercropping finger millet with *Akkadi* in 8 different crop mixtures under 8:1 row proportion recorded higher finger millet grain and straw yield

Research Category: Cropping system

Abbreviations: CRIDA: Central Research Institute for Dryland Agriculture

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