Studies on the effect of *in-situ* soil moisture conservation and nutrient management practices on the productivity of sesame and sorghum in sequence cropping system

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Abstract
A field experiment was carried out in a rainfed situation to study the effect of *in-situ* soil moisture conservation and nutrient management practices (NMP) on productivity of sesame and sorghum in a sequence cropping system. Results indicated that integrated NMP (INMP) with application of organic manures + inorganic fertilizers to preceding sesame and without NMP to succeeding sorghum produced higher seed yield of sesame (566 kg/ha) and sorghum (2531 kg/ha) as compared to NMP either with organic manures alone (211 and 2471 kg/ha, respectively) or with inorganic fertilizers alone (480 and 2347 kg//ha, respectively). The sesame crop showed a similar response to different planting methods. 2:1 or 3:1 skip row method of planting + opening of furrow in skipped row 20 days after sesame sowing alone or with INMP or NMP with application of organic manures to the preceding crop of sesame resulted in higher seed yield of sorghum. *In-situ* soil moisture conservation through 2:1 or 3:1 skip row method of planting along with application of either organic manures or organic manures + inorganic fertilizers to preceding sesame crop and no organic manures and no inorganic fertilizers to succeeding sorghum produced higher yields of both the sesame and sorghum crops in this system.

Key Words
Kharif: rainy season, Rabi: post-rainy season, rainy days, farmyard manure, days after sowing

Introduction
Sesame is predominantly grown during rainy (kharif) season on various soil types in different regions of India. The crop is often subjected to both water logging and soil moisture deficit due to aberration of monsoon in the same season. Many times, even with normal distribution of rainfall, crop suffers from excess soil moisture or moisture stress due to faulty land configuration (methods of planting) which leads to low productivity. It is cultivated mostly in marginal and sub-marginal lands having low organic matter and poor soil fertility. Nutrient stress is another most important factor for low productivity of this crop. Use of organic manure or use of inorganic fertilizers or integrated use of organic manure and inorganic fertilizers helps for sustainable productivity. Sorghum is grown after the harvest of short duration pulse and oilseed crops in areas where the rainfall is fairly well distributed from June to October. To a greater extent the rabi sorghum is grown during post-rainy (rabi) season on stored soil moisture re-filled by the south-west monsoon (June-September). Some times the succeeding crop of sorghum suffers due to insufficient stored soil moisture and erratic rabi season rains. Skip row (2:1 or 3:1) method of planting + opening furrows in skipped rows in preceding crop during kharif season results in better *in-situ* soil moisture conservation/ better harvesting of rain water which favours better storing of soil moisture which ultimately helps the succeeding crop of rabi sorghum. Thus, under double (sequence) cropping system involving sesame and sorghum, skip row method of planting + opening furrows in skipped rows in addition to the nutrient management practices involving organic manures or organic manures + inorganic fertilizers in the preceding sesame crop during kharif season play a major role in improving the productivity of rabi sorghum. Hence, the study was carried out in Northern Transition Zone (Zone 8) of Karnataka State during kharif-rabi on the effect of *in-situ* soil moisture conservation and nutrient management practices during preceding (kharif) season on the productivity of sesame and sorghum in sequence cropping system under rainfed situations.

Methods
A field experiment to study the effect of *in-situ* soil moisture conservation and nutrient management practices on the productivity of sesame and sorghum in sequence cropping system under rainfed farming situations on medium black soil (0.43 % organic carbon, 420 kg available N, 45.8 kg available P_2O_5, 312 kg available K_2O/ha with soil pH 7.8) was conducted during 2006-07 at Main Agricultural Research Station, University of Agricultural Sciences, Krishinagar, Dharwad (Karnataka), India. The experiment consisted of

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three planting methods (*Main plots*) {MP_1 - Flat bed method of planting with a planting geometry 30 cm × 10 cm and plant density of 3,33,333 plants/ha, MP_2 - 2:1 skip row method of planting at planting geometry of 30 cm × 10 cm (2,22,222 plants/ha) (for every 2 rows 1 row is skipped + opening of furrow in skipped rows at 20 days after planting) and MP_3 - 3:1 skip row method of planting at planting geometry of 30 cm × 10 cm (2,50,000 plants/ha) (for every 3 rows 1 row is skipped + opening of furrow in skipped rows at 20 days after planting)} and *three nutrient management practices* (*Sub-plots*){NM_1 - Nutrient management through organic manures (Application of farmyard manure @ 10 t/ha and neem seed cake @ 500 kg/ha + seed treatment with *Trichoderma viride*, phosphate solubilizing bacteria and *Azospirillum*), NM_2 - Nutrient management through the application of inorganic fertilizers (40 kg N, 25 kg P_2O_5, 25 kg K_2O and 5 kg $ZnSO_4$ /ha + seed treatment with Carbendazim @ 2 g/kg seed) and NM_3 - Integrated nutrient management practices involving the application of organic manures and inorganic fertilizers (Recommended dose of fertilizer - 40 kg N, 25 kg P_2O_5 and 25 kg K_2O/ha + farmyard manure @ 5 t/ha + seed treatment with phosphate solubilizing bacteria, *Azospirillum* and Carbendazim). The experiment was laid out in Split Plot Design and replicated three times with an individual gross plot size of 24.84 m^2. All the main plots and sub-plots treatments were imposed for sesame crop during kharif season. FYM was incorporated in soil 20 days before sowing of sesame as per the sub-plot treatments. The sources of fertilizers used in the experiment were urea, diammonium phosphate (DAP) and muriate of potash. The seeds of sesame cv. DS-1 (white and bold seeded) were hand sown. The extra seedlings were thinned out at 15 days after sowing (DAS) to maintain required plant population. In 2:1 and 3:1 skip row method of planting furrows with 20-25 cm depth were opened at 20 DAS with bullock drawn wooden plough. Experimental plots were kept weed free by taking up timely weeding; and insect pests and disease free with suitable plant protection measures. Sesame crop was harvested 95 DAS. Succeeding crop of sorghum (cv. M 35-1) was drill sown with flat bed method of planting at a spacing of 70 cm × 15 cm at 20 days after the harvest of sesame. Succeeding crop of sorghum was planted without any land disturbances and without the application of fertilizers and organic manures.

The rainfall received during the crop growth periods of sesame during kharif (06-07-2006 to 08-10-2006) and sorghum during rabi season (29-10-2006 to 03-03-2007) was 352.7 mm (42 rainy days) (Table 1) and 33.0 mm (02 rainy days) (Table 2), respectively. The rainfall received during the period from harvest of sesame to sowing of sorghum was 18.2 mm (02 rainy days). Sorghum crop was harvested at 125 DAS.

Table 1. Rainfall along with rainy days, mean relative humidity, mean maximum and mean minimum temperatures during different crop growth period of sesame (kharif season).

Crop growth stages	Period (days)	Rainfall (mm)	No. of rainy days	Mean relative humidity (%)	Mean max. temperature (ºC)	Mean min. temperature (ºC)
Seeding to flowering	0-30	153.9	18	87.22	26.4	20.2
Flowering to capsule formation	31-60	94.0	13	83.53	26.8	19.5
Capsule formation to maturity	61-95	104.8	11	79.24	28.9	20.2
Total (Seeding to harvest)	95	352.7	42	83.12	27.4	20.0

Results

Performance of sesame during kharif season

Sesame crop showed similar response to the different methods of planting during kharif season. The seed yield of sesame ranged between 413 to 425 kg/ha due to different methods of planting (Table 3). Higher seed weight/plant was recorded in 2:1 skip row + furrow method (M_2) and 3:1 skip row + furrow methods of planting (M_3). Better individual plant performance in 2:1 skip row + furrow method and 3:1 skip row + furrow method of planting in spite of reduced plant population may be ascribed to the border effects in addition to the advantages obtained in respect of either *in-situ* rain water conservation during flowering to capsule formation and capsule formation to maturity stages and/or draining of excess rain water during seeding to flowering stage of sesame due to the furrows opened in skipped rows. In the present investigation, at later growth stages of sesame especially at harvest, it was observed that 2:1 skip row + furrow method and 3:1 skip row + furrow method of planting recorded higher soil moisture content (32.07 % and 32.46 %, respectively) (Table 4) as compared to flat bed method of planting without any furrow opening (30.90 %). Further, good aeration and exposure of sesame crop canopy to light coupled with better *in-situ* soil moisture conservation in skip row especially in 2:1 skip row + furrow planted crop are the some of the reasons, why skip row methods of planting (either 2:1 or 3:1) in addition to opening of furrows in skipped rows with 2/3rd (2,22,222 plants/ha) or 3/4th (2,50,000 plants/ha) of recommended plant population densities yielded on par with that of flat bed method of planting at recommended plant population density

(3,33,333 plants/ha) (M_3). Similar beneficial effects of skip row method of planting + opening of furrow in skipped row 25 to 30 DAS in increasing yields of peanut under rainfed farming situations was reported earlier (Malligawad 2006). Seed yield of sesame was significantly higher with integrated nutrient management (NM_3) (566 kg/ha) as compared to inorganic nutrient management (NM_2) (480 kg/ha) and organic nutrient management (NM_1) (211 kg/ha). These results are in conformity with the findings of Duhoon *et al*. (2004). The increase in seed yield due to integrated nutrient management may be attributed to higher seed weight plant^{-1} (Table 3). Improvement in growth and yield of sesame due to integrated nutrient management practices may also be attributed to sustained and timely availability of nutrients from the organic sources for longer growth period in addition to the readily available nutrients from the applied fertilizers especially with respect to nitrogen, phosphorus and potassium.

Table 2. Rainfall along with rainy days, mean relative humidity, mean maximum and mean minimum temperatures during the different crop growth period of sorghum (rabi season).

Crop growth stages	Period (days)	Rainfall (mm)	No. of rainy days	Mean relative humidity (%)	Mean max. temperature (ºC	Mean min. temperature (ºC
Seeding to early vegetative	0-30	33.0	2	70.90	29.0	18.3
Early vegetative to late vegetative stage	31-60	0.0	0	61.08	29.2	13.4
Late vegetative stage to blooming	61-90	0.0	0	69.97	30.1	13.2
Blooming to seed maturity	91-125	0.0	0	67.11	31.9	16.0
Total (Seeding to harvest)	125	33.0	2	67.06	30.2	15.3

Table 3. Seed yield of sesame during kharif season and seed yield of sorghum during rabi season in sesame-sorghum sequence cropping system under rainfed farming situation as influenced by planting methods and nutrient management practices.

Nutrient management practices*	Seed yield (kg/ha) of sesame				Seed yield (kg/ha) of sorghum			
	MP_1*	MP_2*	MP_3*	Mean	MP_1*	MP_2*	MP_3*	Mean
NM_1	212	209	211	211	2444	2558	2425	2476
NM_2	393	592	454	480	2244	2482	2314	2347
NM_3	669	439	589	566	2470	2606	2516	2531
Mean	425	413	418	419	2386	2549	2418	2451
Comparing the means of	SE.±		LSD (0.05)		SE.±		LSD (0.05)	
Planting methods (MP)	16.55		NS		27.87		109	
Nutrient management (NM)	12.63		39		23.34		72	
NM at same MP	21.88		67		40.42		125	
MP at same or different NM	24.35		75		43.20		133	

*-Treatments were imposed for preceding sesame crop

Table 4. Moisture content (%) in 0 to 30 cm depth of soil at flowering and at harvest stages of sesame crop during kharif season as influenced by planting methods and nutrient management practices.

Nutrient management practices*	Soil moisture content (%) at different stages of sesame							
	At flowering (60 DAS)				At harvest (95 DAS)			
	MP_1*	MP_2*	MP_3*	MP_1*	MP_1*	MP_2*	MP_3*	Mean
NM_1	22.44	22.42	23.47	23.11	30.50	32.53	32.09	31.71
NM_2	22.14	23.9	22.64	22.66	31.63	32.23	33.54	32.47
NM_3	22.54	22.25	23.16	22.65	30.56	31.44	31.74	31.24
Mean	22.37	22.95	23.09	22.81	30.90	32.07	32.46	31.81

*-Treatments were imposed for preceding sesame crop

Performance of sorghum during rabi season

In sequence cropping system involving sesame and sorghum, effect of different planting methods of preceding sesame crop on the succeeding sorghum crop was significant. It was observed that treatments with 2:1 skip row + furrow method and 3:1 skip row + furrow method followed for sesame planting during preceding kharif season and normal flat bed method of sorghum during succeeding rabi season produced higher seed yield of sorghum (2549 and 2418 kg/ha, respectively) as compared to treatment in which sesame was grown with flat bed method of planting (2386 kg/ha) (Table 4). The higher yield of rabi sorghum in the treatments with 2:1 skip row + furrow method and 3:1 skip row + furrow methods (adopted for sesame cultivation) is ascribed to better availability of soil moisture due to the *in-situ* rain water harvesting at later growth periods of sesame through the furrows opened in the field. Among the different nutrient management practices used for preceding sesame, nutrient management practices either through the application of organic manures only or through the application of organic manures + inorganic fertilizers

and without any nutrient management practices for succeeding rabi sorghum resulted in higher seed yield of sorghum (2476 to 2531 kg/ha) as compared to nutrient management for kharif sesame through inorganic fertilizers and no fertilizers to rabi sorghum (2347 kg/ha). Higher yields of rabi sorghum in organically amended plots in comparison with inorganically amended plots might be due to better and sustained availability of nutrients to succeeding sorghum crop. Highest yield of succeeding rabi sorghum was noticed in plots which received land configuration of 2:1 skip row method of planting + opening of furrows in skipped rows 20 days after sesame sowing along with nutrient management practices involving the application of recommended quantities of organic manures and inorganic fertilizers to preceding sesame.

Conclusion

In sesame-sorghum sequence cropping system under rainfed farming situations, 2:1 skip row method of planting with plant population density of 2,22,222 plants/ha and 3:1 skip row method of planting with plant population density of 2,50,000 plants/ha during kharif season not only produced on par seed yield of sesame with that of flat bed method of planting with plant population density of 3,33,333 plants/ha but also produced higher seed yield of sorghum grown in flat bed method of planting with plant population density of 95,238 plants/ha during Rabi season. Integrated nutrient management practices involving application of organic manures + inorganic fertilizers to preceding sesame crop and without nutrient management practices to succeeding sorghum crop produced higher seed yield of sesame and higher seed yield of sorghum as compared to nutrient management practices either through use of organic manures alone or through inorganic fertilizers alone. *In-situ* soil moisture conservation through 2:1 or 3:1 skip row method of planting along with the application of either organic manures or organic manures + inorganic fertilizers to preceding sesame crop and no organic manures/inorganic fertilizers to succeeding sorghum produced higher yields of sesame and sorghum in sesame-sorghum sequence cropping system.

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