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Effect of preceding legumes, nitrogen levels and irrigation schedules on productivity of sorghum and soil biological activity

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Abstract
The present investigation (2012-2014) explored the possibility of exploiting the beneficial effects of growing dhaincha and its *in situ* incorporation at flowering in *kharif* as a preceding crop to improve the soil physical, chemical and biological status. The experiment was carried out in strip – split plot design with three replications. Four strips of treatments including dhaincha, greengram and cowpea raised as preceding kharif legumes along with fallow are taken as main plot treatments. During *rabi*, sorghum was grown in split plot design taking strips of *kharif* crops as main plots, four irrigation schedules assigned to sub plots and four nitrogen levels *viz.*, 0, 30, 60 and 90 kg ha^{-1} to sub sub plots. The microbial population viz., bacteria, fungi and actinomycetes were found in large number in the rhizosphere of sorghum in response to the preceding *kharif* legumes. Higher bacteria (74 × 106 CFUg^{-1} of soil), fungi (15 × 104 CFUg^{-1} of soil) and actinomycetes (33 × 103 CFUg^{-1} of soil) were found with green manuring *i.e.* dhaincha *in situ* incorporation in preceding *kharif* season. Highest microbial population was observed with irrigation at four critical stages. The microbial population in rhizosphere of sorghum increased significantly (bacteria: 22-60 × 106), (fungi - 05 - 14 × 104) and (actinomycetes: 13-28 × 103) with application of nitrogen 30 to 60 kg N ha^{-1} and thereafter the increase was insignificant. Higher grain yield of sorghum was obtained by growing dhaincha for green manure or greengram for seed with four irrigations at critical phases of panicle initiation, booting, anthesis and milk stage along with application of 60 kg N ha^{-1}.

Keywords: Preceding legumes, nitrogen levels, irrigation schedules on productivity of sorghum and soil biological activity

Introduction

Nutrients contained in organic manures are released more slowly and stored for a long time in the soil, ensuring a long residual effect (Sharma and Mitra, 1988) [22] which support better root development leading to higher crop yields (Mahajan, 2007) [11]. Safety of environment as well as public health is also an important reason for advocating increased use of organic materials (Hazra, 2007) [7]. However, the use of organic manure alone, cannot sustain the cropping system due to unavailability of required quantities and their relatively low nutrient content (Palm *et al.*, 1997) [14].

Application of chemical fertilizers in conjunction with organic/ green manures will sustain and maintain the productivity of soil. Therefore, it is necessary to find out integration various organic/ green manures with chemical fertilizers in order to find out the most effective combination. *Kharif* legumes fix up atmospheric N in soil and their inclusion in the crop rotation helps in improving physico-chemical and biological properties of soil (Sharma *et al.*, 1986) [23].

Hence, a strategy of integrated use of nitrogen through fertilizer in combination with any amount of cheaper organic source which is abundantly available should be tried to satisfy the higher nitrogen requirement of the crop in order to produce higher yields without impairing the soil health. Organic manures and crop residues have been proved to be viable components of nitrogen management, which can supplement and successfully replace costly fertilizer nitrogen. Therefore, a study was conducted to maximize the productivity and economic returns of the *kharif* legumes – *rabi* sorghum cropping sequence, by developing appropriate and viable nitrogen management practices, without any degradation of soil health.

Material and Methods

A field experiment was conducted at the Research Farm of Indian Institute of Millets Research (IIMR) (formerly Directorate of Sorghum Research), Rajendranagar, Hyderabad to study the post harvest soil fertility and biological status as influenced by preceding legumes, nitrogen levels and irrigation schedules for two consecutive years (2012-2013 and 2013-2014). The study was taken up in a strip-split plot design with three replications. Four strips of treatments including dhaincha, greengram and cowpea raised as preceding kharif legumes along with fallow are taken as main plot treatments. Four irrigation schedules (I_1: Irrigation at panicle initiation, I_2: Irrigation at panicle initiation and booting, I_3: Irrigation at panicle initiation, booting and anthesis and I_4: Irrigation at panicle initiation, booting, anthesis and milk stages) assigned to sub – plots and four nitrogen levels (0, 30, 60 and 90 kg ha-1) to sub – sub plots respectively. Before sowing of kharif crops and rabi sorghum and after harvest of sorghum, soil samples were collected as per treatment wise up to 30 cm depth and analysed. In order to assess the fluctuations in the microbial status of the preceding *kharif* legumes – *rabi* sorghum field, soil samples were collected after incorporation / before sowing rabi sorghum, at 50% flowering and at harvest during 2012-13 and 2013-14, the microbial studies were enumerated.

Microbial Studies

Methodology:

Soil samples were collected at 0-15 cm depth in five locations and pooled as such when wet. The samples were diluted serially by transferring 10 g to a 250 ml Erlenmeyer flask containing 90 ml of sterile distilled water and the contents were shaken in a rotary shaker for 10 minutes. Using sterile pipette, 10 ml of the suspension was transferred to 90 ml of sterile water and likewise serial dilutions were continued using sterile distilled water till 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were obtained. Aliquots of 1 ml of appropriate dilution were plated. Total bacteria were enumerated in nutrient agar, fungi in Martin's Rose Bengal agar, actinomycetes in Kenknight's agar. The plates were incubated at a room temperature of 30 ± 2°C and counts were made after 3 days for bacteria, 3-5 days for fungi and 7 days for actinomycetes. Microbial biomass carbon was estimated by the method of Nunan *et al.* (1998) [14].

Results and Discussion

Grain Yield

Perusal of the data (Tables 1) indicated that significantly higher grain yield (2511 kg ha^{-1} in 2012 and 3024 kg ha^{-1} in 2013) of sorghum was obtained by incorporation of the entire biomass of dhaincha grown in the preceding *kharif*. Lowest grain yield was with sorghum when grown after *kharif* fallow (2409 and 2930 kg ha^{-1} in 2012 and 2013, respectively). Grain yield of sorghum was comparable to the crop grown after cowpea for fodder or greengram for seed. However, during 2013, sorghum preceded by dhaincha recorded the higher grain yield, which was however comparable with crop grown after greengram or cowpea. Lowest grain yield of sorghum was recorded when grown after fallow which was however on par with cowpea or greengram as preceding crops. Preceding legumes might have added nitrogen to sorghum through fixation and mineralization of their biomass in soil through root nodules, roots, leaves *etc*. to benefit higher grain yield of succeeding *rabi* sorghum. These benefits probably accrued through cumulative positive influence on vegetative growth, dry matter per plant, number of grains per panicle and ear head weight, and nutrient uptake which in turn probably was the result of relatively faster decomposition of dhaincha. The beneficial effects of *kharif* legumes on *rabi* sorghum were also reported by Pawar *et al.* (1995a) [16], Nagre and Chandrasekhar (1988) [13]. Mishra *et al*. (2011) [12] also reported that green manure of dhaincha increased the production of sorghum compared to the yield from fallow - sorghum.

Among preceding legumes, significantly higher grain yield was noticed with the crop preceded by dhaincha green manuring might be attributed to less lignin content, more favorable narrow C: N ratio and high N content of dhaincha which caused faster N mineralization leading to high N availability. In view of the above facts beneficial effects of legume crop residues may also ascribed to the apparent agronomic advantage from green manures. These results are in accordance with Tamboli *et al.* (2011) [28] and Rosegrant and Roumossel (1987) [19]. Similarly in the earlier investigations, Sabale *et al*. (1981) [20] and Pol *et al*. (1982) [17] recorded higher grain yield of sorghum preceding blackgram than greengram. The usefulness of N_2 fixing legumes and their positive impact on soil fertility by enhancing nitrogen availability and thereby benefitting a cereal crop grown in the subsequent season was confirmed by Armstrong *et al.* (1999) [1] and Sanginga (2003) [21].

Microbial population

Microbial population *i.e.*, bacteria, fungi and actinomycetes in rhizosphere of sorghum revealed that irrespective of treatments soil bacteria, fungi and actinomycetes reached its maximum value at 50% flowering and declined thereafter during both the years of study (Table 2 to 4). The total bacteria, fungi and actinomycetes were found in large number in the soil during *Kharif* season of 2013. However, it varied with the fallow and cropping period. Microbial population in the rhizosphere of sorghum in response to the preceding *kharif* legumes was higher *i.e.*, bacteria (74 × 10^6 CFUg^{-1} of soil), fungi (15 × 10^4 CFUg^{-1} of soil) and actinomycetes (33 × 10^3 CFUg^{-1} of soil) with green manuring *i.e.* dhaincha *in situ* incorporation in preceding *kharif*. Statically on par results were observed with preceding cowpea for fodder and green gram for seed. However, lowest microbial population was recorded when the soil was left fallow preceeding to *rabi* sorghum. Beare *et al.* (1996) [4] reported increase in microbial population with incorporation of green manure crops. Sushila and Gajendra Giri (2000) [27] reported increased microbial population in the rhizosphere of wheat in the presence of organic manure. Tamboli *et al.* (2011) [28] observed that the application of green manuring increased the organic carbon content of soil, and directly influences the microbial growth. The results also revealed that microbial count was the highest at the time of 50% flowering for total bacteria, fungi, actinomycetes.

Among four irrigation schedules at panicle initiation, booting, anthesis and milking stages, anthesis stage recorded highest number of microbes *i.e.* bacteria (57 - 66 X 10^6 CFUg^{-1} of soil), fungi (12 - 14 X 10^4 CFUg^{-1} of soil) and actinomycetes (24 - 28 X 10^3 CFUg^{-1} of soil), in the rhizosphere of sorghum followed by irrigation at panicle initiation, booting and anthesis. Higher microbial population with scheduling of irrigation four times during critical phases might be due to higher moisture content during crop growth period which directly influences the microbial growth. Similar trends were observed during both the years of experimentation.

The microbial population in rhizosphere of sorghum increased significantly (bacteria: 22-60 × 10^6 CFUg^{-1} of soil), (fungi - 05 - 14 × 10^4 CFUg^{-1} of soil) and (actinomycetes: 13-28 × 10^3 CFUg^{-1} of soil) with application of nitrogen 30 to 60 kg N ha^{-1} and thereafter the increase was insignificant.

Microbial Biomass Carbon

It is evident from the results (Tables 3 to 6) that during both the years of study irrespective of the treatments in the rhizosphere of sorghum, soil microbial biomass carbon reached its maximum at 50% flowering. Microbial biomass carbon differed with fallow significantly with different legumes grown preceding to *rabi* sorghum. Among them, incorporation of entire foliage of dhaincha at 50% flowering recorded highest microbial biomass carbon followed by green gram for seed and cowpea for fodder respectively and the lowest when the soil was left fallow preceding to *rabi* sorghum. The microbial population directly influenced the microbial biomass carbon in the soil and nutrient uptake which inturn probably was due to the faster decomposition of dhaincha. The green manure incorporation provided the substrate for different microflora and inorganic compounds. Azamal *et al.* (1996) [2] and Sridevi *et al.* (2003) [26] reported a marked increase in microbial biomass following incorporation of crop residues.

Irrigation schedules had an explicit influence on the microbial biomass carbon. The irrigation at critical stages *i.e.* panicle initiation, booting, anthesis and milking stage recorded highest microbial biomass. It might be due to the high moisture content in the soil which directly influenced the microbial population and also improved the organic compounds in the soil which in turn increase the microbial biomass carbon. The results are in conformity with Rangaswami and Venkatesam (1964) [18]. They reported that high moisture content proliferates the microflora which increases the microbial biomass carbon.

Highest microbial biomass carbon in the rhizosphere of sorghum was recorded with application of nitrogen 30 to 60 kg N ha^{-1} and thereafter the increase was insignificant. The highest microbial biomass carbon recorded with 60 kg N application at flowering stage was 376 and 389 µg g^{-1} of soil during 2012 and 2013 respectively. Similarly Singh (1991) [25] reported that application fertilizer in rice - lentil crop rotation has increased the soil microbial biomass carbon. The interactions owing to combined influence of different treatments were not significant on the microbial population and microbial biomass carbon at different stages of crop growth.

The incorporation of organic matter regenerates depleted soil resources and promote sustainable food production. Kumar and Goh (2000) [8] reported that the decomposition of crop residues is a microbial - mediated progressive break down of organic materials with ultimate end products of carbon and nutrients released into the biological circulation. The green manure of dhaincha in the present investigation perhaps activated the soil biota, improved the soil physical properties and released the nutrients especially the depleting micronutrients in addition to the major and secondary nutrients. Incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations. If all the factors are ideal for fast decomposition, it is likely to release about 60.0 kg N ha^{-1} in the first year and 64.0 kg ha^{-1} in the second year. This is mineralized slowly and released into the soil for availability to the crop later in a period of 3 to 5 years. Ladd *et al.* (1983) [9] reported that about 20% of the mineralized nitrogen is likely to be available to the succeeding crop. Harris *et al.* (1994) [6] reported that < 30% N is contributed by the decomposed green manures to the following crop. Large amounts of legume were retained in the soil mostly in organic forms. Hence, it is expected that utmost 12 - 18 kg N ha^{-1} might have been added to the soil organic pool by dhaincha in the present investigation. This is meager to improve the fertility status of soil nitrogen in a short time. Singh *et al.* (2005) [24] reported that the crop residues - the harvest remnants of the previous crop - play an essential role in the cycling of nutrients. Incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations.

The incorporation of mature and less succulent foliage with depleted nutrients, dried and fallen leaves of greengram after picking of pods was perhaps not sufficient to improve the crop growing conditions for sorghum in a relatively short time as that of dhaincha in the present investigation. The addition of stubbles alone after the harvest of cowpea fodder was also not sufficient to build up fast microbial activity and improve the soil. Ascertaining dissimilar potential of legumes, Gaikwad *et al.* (1993) [5] recorded significant increase in grain and fodder yield of sorghum preceding cowpea than blackgram, soybean or fallow in medium black soil having low OC of 0.42%. Bangar *et al.* (2003) [3] on the other hand recorded significant increase in grain and fodder yield of sorghum preceding fallow than the cultivation of blackgram, greengram or soybean in vertisol having a moderate status in OC (0.54%) but low level of 143 kg N ha^{-1}. Larue and Patterson (1981) [10] inferred from an extensive review that there was not a single legume crop for which agronomists had valid estimates of symbiotic nitrogen fixation rate.

Table 1: Grain and Stover yield (kg ha^{-1}) of sorghum as influenced by irrigation schedules and levels of nitrogen preceded by *kharif* legumes

Treatment	Grain yield (kg ha^{-1})		Stover yield (kg ha^{-1})	
	2012	2013	2012	2013
Preceding legumes in *kharif*				
C_1: Sorghum preceded by Dhaincha	2511	3024	5686	6127
C_2: Sorghum preceded by Greengram for seed	2446	2942	5487	6063
C_3: Sorghum preceded by Cowpea for fodder	2389	2947	5441	5999
C_4: Sorghum preceded by Fallow	2409	2930	5367	6019
S Em ±	17.0	24.8	7.8	8.5
CD at 5%	59	85	27	29
Irrigation schedules				
I_1: Panicle initiation	2338	2870	5311	5830
I_2: PI and booting	2413	2929	5419	5953
I_3: PI, booting and anthesis	2477	2997	5570	6141
I_4: PI, booting, anthesis and milk stage	2528	3047	5681	6286
S Em±	13.4	6.4	36.1	37.5

CD at 5%	46	22	124	131
Nitrogen (kg ha^{-1})				
N_1: No Nitrogen	2039	2466	4863	5311
N_2: 30	2380	2886	5305	5833
N_3: 60	2650	3222	5708	6338
N_4: 90	2686	3269	6104	6726
S Em ±	54.5	57.3	131.5	140.0
CD at 5%	188	199	457	484
Interaction				
Kharif legumes × Irrigation				
S Em ±	46.0	64.4	49.5	54.5
CD at 5%	NS	NS	NS	NS
Kharif legumes × Nitrogen				
S Em ±	190.9	204.4	456.9	484.4
CD at 5%	NS	NS	NS	NS
Irrigation × Nitrogen				
S Em ±	189.5	199.4	461.8	485.1
CD at 5%	NS	NS	NS	NS
Kharif legumes × Irrigation × Nitrogen				
S Em ±	54.5	57.3	131.5	140.0
CD at 5%	NS	NS	NS	NS

Table 2: Soil bacteria x 10^6 CFU g^{-1} of soil at different stages as influenced by irrigation and levels of nitrogen preceded by *kharif* legumes

Treatment	After incorporation / before sowing *rabi* sorghum		At 50% flowering		At harvest	
	2012	2013	2012	2013	2012	2013
Preceding legumes in *kharif*						
C_1: Dhaincha	24	29	61	74	42	50
C_2: Greengram for seed	21	25	43	61	30	36
C_3: Cowpea for fodder	21	23	43	53	29	39
C_4: Fallow	20	19	28	39	21	25
S Em ±	0.21	0.28	0.28	0.35	0.21	0.28
CD at 5%	0.7	0.9	1.0	1.2	0.7	0.9
Irrigation schedules						
I_1: Panicle initiation	21	23	32	47	25	33
I_2: PI and booting	22	23	37	51	28	35
I_3: PI, booting and anthesis	22	24	50	63	33	40
I_4: PI, booting, anthesis and milk stage	22	24	57	66	37	43
S Em ±	0.07	0.07	0.07	0.14	0.14	0.14
CD at 5%	0.2	0.2	0.3	0.4	0.5	0.5
Nitrogen (kg ha^{-1})						
N_1: No Nitrogen	20	22	40	50	28	35
N_2: 30	22	23	43	57	30	37
N_3: 60	22	24	46	60	32	39
N_4: 90	23	24	46	61	32	39
S Em ±	0.50	0.71	0.99	1.34	0.85	1.06
CD at 5%	1.4	NS	2.8	3.7	2.3	3.0
Interaction						
Kharif legumes × Irrigation						
S Em ±	0.42	0.57	0.78	0.85	0.42	0.85
CD at 5%	NS	NS	NS	NS	NS	NS
Kharif legumes × Nitrogen						
S Em ±	1.77	2.33	3.54	4.67	2.90	3.75
CDat 5%	NS	NS	NS	NS	NS	NS
Irrigation × Nitrogen						
S Em ±	1.77	2.33	3.47	4.60	2.83	3.75
CDat 5%	NS	NS	NS	NS	NS	NS
Kharif legumes ×Irrigation × Nitrogen						
S Em ±	0.50	0.64	0.99	1.34	0.85	1.06
CDat 5%	NS	NS	NS	NS	NS	NS

Initial : 16 ×10^6 CFU g^{-1} of soil

Table 3: Soil fungi ×10^4 CFU g^{-1} of soil at different stages as influenced by irrigation and levels of nitrogen preceded by *kharif* legumes

Treatment	After incorporation /before sowing *rabi* sorghum		At 50% flowering		At Harvest	
	2012	2013	2012	2013	2012	2013
Preceding legumes in *kharif*						
C_1: Dhaincha	5	7	12	15	9	10
C_2: Greengram for seed	5	6	11	13	8	9
C_3: Cowpea for fodder	4	5	10	12	7	7
C_4: Fallow	3	5	8	11	5	6
S Em ±	0.07	0.07	0.07	0.07	0.07	0.14
CD at 5%	0.2	0.2	0.3	0.3	0.3	0.4
Irrigation schedules						
I_1: Panicle initiation	4	6	9	12	6	7
I_2: PI and booting	4	5	10	12	6	8
I_3: PI, booting and anthesis	5	6	11	14	7	8
I_4: PI, booting, anthesis and milk stage	5	6	12	14	9	10
S Em ±	0.07	0.07	0.07	0.07	0.03	0.07
CD at 5%	0.2	0.3	0.3	0.3	0.12	0.2
Nitrogen (kg ha^{-1})						
N_1: No Nitrogen	4	6	10	12	6	8
N_2: 30	5	6	10	13	7	8
N_3: 60	5	6	11	14	8	9
N_4: 90	5	6	11	13	7	9
S Em ±	0.14	0.14	0.21	0.28	0.14	0.21
CD at 5%	0.3	0.4	0.7	0.9	0.4	0.6
Interaction						
Kharif legumes × Irrigation						
S Em ±	0.21	0.28	0.21	0.28	0.28	0.35
CD at 5%	NS	NS	NS	NS	NS	NS
Kharif legumes × Nitrogen						
S Em ±	0.42	0.50	0.85	1.06	0.57	0.78
CD at 5%	NS	NS	NS	NS	NS	NS
Irrigation ×Nitrogen						
S Em ±	0.42	0.50	0.85	1.06	0.57	0.71
CD at 5%	NS	NS	NS	NS	NS	NS
Kharif legumes ×Irrigation × Nitrogen						
S Em ±	0.14	0.14	0.21	0.28	0.14	0.21
CD at 5%	NS	NS	NS	NS	NS	NS

Initial : 04 ×10^4 CFU g^{-1} of soil

Table 4: Soil actinomycetes ×10^3 CFU g^{-1} of soil at different stages as influenced by irrigation and levels of nitrogen preceded by *kharif* legumes

Treatment	After incorporation / before sowing *rabi* sorghum		At 50% flowering		At Harvest	
	2012	2013	2012	2013	2012	2013
Preceding legumes in *kharif*						
C_1: Dhaincha	17	21	26	33	18	22
C_2: Greengram for seed	13	18	22	28	16	19
C_3: Cowpea for fodder	13	16	20	23	16	15
C_4: Fallow	10	13	16	21	10	13
S Em ±	0.07	0.07	0.07	0.14	0.14	0.14
CD at 5%	0.2	0.2	0.3	0.5	0.4	0.5
Irrigation schedules						
I_1: Panicle initiation	12	18	17	24	12	15
I_2: PI and booting	13	17	20	25	14	17
I_3: PI, booting and anthesis	14	17	23	28	16	18
I_4: PI, booting, anthesis and milk stage	15	17	24	28	18	19
S Em ±	0.07	0.07	0.14	0.14	0.07	0.07
CD at 5%	0.2	0.2	0.5	0.4	0.9	0.2
Nitrogen (kg ha^{-1})						
N_1: No Nitrogen	13	16	20	24	13	15
N_2: 30	13	17	21	26	15	17
N_3: 60	14	17	22	28	16	19
N_4: 90	14	18	21	27	16	18
S Em ±	0.28	0.42	0.50	0.71	0.35	0.42
CD at 5%	0.8	1.1	1.5	2.0	0.9	1.3
Interaction						
Kharif legumes × Irrigation						
S Em ±	0.21	0.21	0.21	0.35	0.35	0.42
CD at 5%	NS	NS	NS	NS	NS	NS
Kharif legumes × Nitrogen						

S Em ±	1.06	1.41	1.84	2.48	1.20	1.56
CD at 5%	NS	NS	NS	NS	NS	NS
Irrigation × Nitrogen						
S Em ±	1.06	1.41	1.84	2.48	1.20	1.56
CD at 5%	NS	NS	NS	NS	NS	NS
Kharif legumes ×Irrigation × Nitrogen						
S Em ±	0.28	0.42	0.50	0.71	0.35	0.42
CD at 5%	NS	NS	NS	NS	NS	NS

Initial: 12 ×10^3 CFU g^{-1} of soil

Table 5: Soil Microbial biomass carbon µg g^{-1} of soil at different stages as influenced by irrigation and levels of nitrogen preceded by *kharif* legumes

Treatment	After incorporation / before sowing *rabi* sorghum		At 50% flowering		At harvest	
	2012	2013	2012	2013	2012	2013
Preceding legumes in *kharif*						
C_1: Dhaincha	324	341	464	468	367	380
C_2: Greengram for seed	255	279	355	366	279	293
C_3: Cowpea for fodder	237	253	322	360	272	281
C_4: Fallow	213	210	269	257	236	235
S Em ±	0.92	1.13	0.78	0.85	0.28	0.04
CD at 5%	3.2	3.8	2.6	3.0	1.1	0.14
Irrigation schedules						
I_1: Panicle initiation	252	262	267	306	217	240
I_2: PI and booting	248	258	325	339	271	280
I_3: PI, booting and anthesis	253	267	392	390	317	316
I_4: PI, booting, anthesis and milk stage	275	296	427	416	349	352
S Em ±	0.57	1.06	0.99	0.92	0.28	0.04
CD at 5%	2.0	3.6	3.4	3.3	1.1	0.14
Nitrogen (kg ha^{-1})						
N_1: No Nitrogen	246	256	325	335	267	266
N_2: 30	260	271	355	364	289	301
N_3: 60	266	278	376	389	311	324
N_4: 90	256	277	353	362	287	299
S Em ±	4.95	5.94	7.92	8.20	5.52	6.29
CD at 5%	13.8	16.6	22.2	23.0	15.5	17.7
Interaction						
***Kharif* legumes x Irrigation**						
S Em ±	3.47	4.03	2.19	2.62	1.70	0.14
CD at 5%	NS	NS	NS	NS	NS	NS
***Kharif* legumes x Nitrogen**						
S Em ±	17.11	20.65	27.51	28.50	19.09	21.78
CDat 5%	NS	NS	NS	NS	NS	NS
Irrigation x Nitrogen						
S Em ±	17.11	20.58	27.51	28.50	19.09	21.78
CD at 5%	NS	NS	NS	NS	NS	NS
***Kharif* legumes x Irrigation x Nitrogen**						
S Em ±	4.95	5.94	7.92	8.20	5.52	6.29
CD at 5%	NS	NS	NS	NS	NS	NS

Conclusion

From the present investigation, it could be inferred that *rabi* sorghum preceded by dhaincha for green manure or greengram for seed with four irrigations at critical phases of panicle initiation, booting, anthesis and milk stage along with application of 60 kg N ha^{-1} has resulted in higher yield and more economic returns. Further, it also increases the microbial population and microbial biomass in the soil which in turn increases the soil fertility and ultimately increasing their production.

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