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Research Paper

Effect of integrated nutrient management on growth, productivity and quality of sweet sorghum (*Sorghum bicolor*)

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ABSTRACT

A field experiment was conducted during 2007–08 at Nagla, Pantnagar, Uttarakhand, to find out effect of organic and inorganic sources of nutrients on growth, productivity and quality of sweet sorghum [*Sorghum bicolar* (L.) Moench] forage crop. The experiment was laid out in a randomized block design consisting total 12 treatments with 4 replications. Treatments comprised control, recommended dose of NPK through inorganic source and different combinations of organic and inorganic sources of nutrients. Application of 75% dose of recommended nitrogen through inorganic sources + 25% through vermicompost significantly improved the growth, productivity and fodder quality over the control. The highest total green fodder yield (52.8 t/ha), dry-matter yield (13.5 t/ha), total crude protein yield (0.92 t/ha), digestible dry-matter yield (6.6 t/ha), juice yield (9,910 kilo litre/ha), sugar yield (0.91 t/ha) and calculated ethanol yield (2,762 kilo litre/ha) was recorded with application of 75% recommended dose of N through inorganic sources + 25% through vermicompost during both the years. Fodder quality parameters like juice percentage (26.2), dry-matter content (25.6%), digestibility (48.7%) and neutral detergent fibre content (61%) were also highest with this treatment. Available nitrogen and phosphorus content did not vary significantly at harvesting of crop due to different treatments.

Key words : Fodder quality, Organic and inorganic sources, Productivity, Soil fertility, Sweet sorghum

The success of livestock industry depends on feeding the animals with sufficient quantity of nutritious forage to meet their requirements for maintenance, growth and production. At present, India has nearly 40% short supply of green forage production. Since the forages are the low-priced source of animal feed (Joshi *et al.,* 2007); the gap between demand and supply can be bridged up with increase in productivity of forage crops. Sweet sorghum, is a special type of forage sorghum, which has the ability to accumulate fermentable sugars (15–17%) in its stalk. It is the only crop which provides green fodder, grain and stem that can be used for chewing, sugar, alcohol, syrup, jaggery, roofing, fencing and paper manufacturing. Stalk, which is the main storage for juice of sweet sorghum, contributes maximum portion of biomass, i.e. up to 70–80%. Sweet sorghum has many characteristics such as wide adaptability, tolerance to abiotic stresses like drought, waterlogging, salinity and alkalinity and capacity to grow quickly. Because of these characteristics, it has been used for nearly 150 years to produce concentrated syrup with distinctive flavour.

To maintain good health and potential of animals in terms of draft, milk, meat and wool, feeding of quality fodder is more important. The high yielding varieties of forage crops and agronomic techniques may be helpful to achieve this goal. The forage crops are heavy feeder of plant nutrients and also removes large amount of nutrients from the soils. For harvesting full forage-quality potential, forage crops requires liberal supplementation of nutrients, addition of external fertilizers and manures to meet the nutritional requirements of crop. Hence nutrient-management of forage crops is most important. The complimentary use of chemical fertilizers and organic manures help in achieving sustainable forage production in specified time by not only augmenting the efficiency of applied fertilizer, but also through correction of secondary and micronutrient deficiency. Hence the increasing cost of fertilizers and poor economic condition of farmers make it imperative to adopt integrated nutrient-management. It has been

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studied that organic manures can supplement the requirement of nutrition in forage crops (Sharma, 1981). It is therefore, needed to find out alternatives to minimize the dependence on inorganic fertilizers without affecting the nutritional supply to the crop plants. Information on these aspects particularly in forage crops is lacking. Keeping these points in view, the present study was undertaken to find out the response of sweet sorghum to different sources of nutrients.

MATERIALS AND METHODS

The experiment was conducted in Forage Agronomy block of Instructional Dairy Farm, Nagla at the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand. The Instructional Dairy Farm is located in the foothills belt of Shivalik range of Himalayas with humid sub-tropical type of climate at latitude of 29° N and longitude of 79.3° E and situated at an altitude of 243.84 m above the mean sea-level. The mean annual rainfall was 1,369 mm of which 80 to 90% is received from June to October. The soil of experimental field was slight silty clay loam (Nagla series, Mollisol) in texture, dark grayish brown to dark grey in humus with weak fine to medium granular structure. The soil of experimental field was high in organic carbon (0.78) (Walkley and Black, 1934), medium in available nitrogen (281.5), (Subbiah and Asija, 1956), available phosphorus (26.4) (Olsen's *et al.,* 1954) and available potassium (247.1 kg/ha) (Hanway and Heidel, 1952). The soil *p*H was neutral (7.42).

The experiment was laid out in a randomized block design, consisting total 12 treatments with 4 replications. Treatments comprised different combinations of inorganic and organic fertilizers and their doses including the control recommended dose of NPK through inorganic source, 75% recommended dose of N (RDN) through inorganic source + 25% through farmyard manure (FYM), 75% RDN through inorganic source + 25% through vermicompost, 50% RDN through inorganic source + 50% through FYM, 50% RDN through inorganic source + 50% through vermicompost, 75% RDN through inorganic source + 25% through FYM, + biofertilizers, 75% RDN through inorganic source + 25% through vermicompost + biofertilizers, 50% RDN through inorganic source + 50% through FYM + biofertilizers, 50% RDN through inorganic source + 50% through vermicompost + biofertilizers, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + biofertilizers. *Azospirillum* spp. was used as biofertilizer in sweet sorghum crop. The recommended dose of N, P and K for sweet sorghum was 120:50:50 kg NPK/ha.

Variety 'RSSV 9' of sweet sorghum was used for the experimentation. The required amount of farmyard manure (containing 0.5% N, 0.2% P_2O_5 and 0.5% K_2O) and vermicompost (containing 2.0% N, 1.2% P_2O_5 and 0.8% K_2O) was calculated and applied with respect to the respective treatments. Urea, single superphosphate and muriate of potash were used as inorganic source of nitrogen, phosphorus and potassium respectively. The crop was sown on 3 July 2007 and 9 July 2008 and harvested on 3 November 2007 and 10 November 2008 during first and second year of experimentation respectively. Other cultural practices were followed as per the recommendation about this crop. Digestibility was estimated with the help of nylon bag method given by Lowery (1969), for the crude protein estimation pooled ground samples were analysed for nitrogen content by micro-Kjeldahl method (Jackson, 1973). The neutral detergent fibre (NDF) was estimated using the method of Goering and Van Soest (1970).

Data obtained from 2 consecutive years were pooled together and analysed statistically as per the procedure given by Cochran and Cox (1966). In case of significant results, critical difference (CD at 5%) was calculated for testing the significance of the difference between 2 treatments at 5% level of probability.

RESULTS AND DISCUSSION

Growth and development

At harvesting 120 days after sowing (DAS), treatment having 75% RDN through inorganic source + 25% through vermicompost + BF recorded significantly taller plants than the control, which was statistically at par with rest of the treatments. Control treatment recorded significantly smaller plants than rest of the treatments (Table 1). At 120 DAS, 75% RDN through inorganic source + 25% through FYM + BF being at par with each other recorded significantly higher, leaf area index (LAI) than the control. Control treatment recorded singnificantly lesser LAI than all other treatments.

At 120 DAS, the dry-matter accumulation was the highest with 75% RDN through inorganic source + 25% through vermicompost + BF and it was significantly higher than the control, 50% RDN through inorganic source + 50% through FYM, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF, 33% RDN through inorganic source + 33% through FYM + 33 through vermicompost and 50% RDN through inorganic source + 50% through vermicompost..

Application of 75% RDN through inorganic source + 25% through vermicompost + BF recorded the highest growth and development parameters, viz. plant height, leaf-area index and total dry-matter accumulation (all at 120 DAS). Increase in growth parameters combined use of organic and inorganic fertilizers might be owing to availability of plant nutrients throughout the growth period as suggested by Arya *et al.* (2000).

Productivity

Data on total green fodder yield, dry-matter yield, total crude protein yield, digestible dry-matter yield, juice yield, sugar yield and calculated ethanol yield are given in Table 2. The highest total green fodder yield was recorded with 75% RDN dose through inorganic source + 25% through vermicompost + BF and it was significantly superior to the control, 50% RDN through inorganic source + 50% through vermicompost, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF. The control produced significantly lesser total green fodder yield than the rest of the treatments.

Application of 75% RDN through inorganic source + 25% through vermicompost + BF recorded significantly higher dry-matter yield than rest of the treatments except recommended dose of NPK through inorganic source, 75% RDN through inorganic source + 25% through vermicompost, 50% RDN through inorganic source + 50% through vermicompost, 75% RDN through inorganic source + 25% through FYM + BF and 50% RDN through inorganic source + 50% through vermicompost + BF. Significantly lower dry-matter yield was recorded in the control than rest of the treatments.

Total crude protein yield, was the highest with application 75% RDN through inorganic source + 25% through vermicompost + BF and it was significantly higher than the control, 75% RDN through inorganic source + 25% through FYM and 50% RDN through inorganic source + 50% through FYM. For digestible dry-matter yield, application of 75% RDN through inorganic source + 25% through vermicompost + BF being at par with 75% RDN through inorganic source + 25% through FYM + BF and 50% RDN through inorganic source + 50% through vermicompost + BF and 75% RDN through inorganic source + 25% through vermicompost recorded significantly higher digestible dry-matter yield than remaining treatments. Control gave significantly less digestible dry-matter yield than rest of the treatments.

Application of 75% RDN through inorganic source + 25% through vermicompost + BF resulted in the highest juice yield and it was significantly higher than the control, 75% RDN through inorganic source + 25% through FYM, 50% RDN through inorganic source + 50% through FYM, 50% RDN through inorganic source + 50% through vermicompost, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF. Under the control treatment significantly lesser juice yield was recorded than rest of the treatments during both the years.

Application of 75% RDN through inorganic source + 25% through vermicompost + BF recorded significantly more sugar yield than the control, 75% RDN through inorganic source + 25% through FYM, 50% RDN through

Table 1. Effect of nutrient-management treatments on plant height, leaf-area index and total dry-matter accumulation in sweet sorghum

Treatment	Plant height at 120 DAS (cm)	Leaf area index at 120 DAS	Total dry-matter accumulation g/m^2 at 120 DAS
Control	225	2.5	677
RD NPK through inorganic source	321	3.9	1,398
75% RDN through inorganic source + 25% through FYM	315	3.9	1,331
75% RDN through inorganic source + 25% through VC	325	4.0	1,424
50% RDN through inorganic source + 50% through FYM	317	3.7	1,241
50% RDN through inorganic source + 50% through VC	320	3.8	1,334
75% RDN through inorganic source + 25% through FYM + BF	339	4.2	1,478
75% RDN through inorganic source + 25% through VC + BF	345	4.2	1,521
50% RDN through inorganic source + 50% through FYM + BF	329	4.0	1,408
50% RDN through inorganic source + 50% through VC + BF	332	4.1	1,444
33% RDN through inorganic source + 33% through FYM + 33 through VC	306	3.5	1,268
33% RDN through inorganic source + 33% through FYM + 33% through VC + BF	319	3.8	1,307
SEm±	17	0.2	65
CD (P=0.05)	50	0.7	188

DAS, Days after sowing; RD, recommended dose; RDN, recommended dose of nitrogen; FYM, farmyard manure; BF, biofertilizers; VC, vermicompost inorganic source + 50% through FYM, 50% RDN through inorganic source + 50% through vermicompost, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF. Control recorded significantly lesser sugar yield than remaining treatments except 50% RDN through inorganic source + 50% through FYM during both the years.

The highest calculated ethanol yield was recorded with 75% RDN through inorganic source + 25% through vermicompost + BF, being superior to the control, 75% RDN through inorganic source + 25% through FYM, 50% RDN through inorganic source + 50% through vermicompost, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF. The control recorded significantly lesser calculated ethanol yield than rest of treatments except 50% RDN through inorganic source + 50% through FYM.

In general, all yield parameters were recorded higher with application of 75% RDN through inorganic sources + 25% through vermicompost. Our findings confirm the results of Singh (2009), who also reported higher green forage and dry-matter yield by integration of inorganic and organic sources of nutrition. Higher yield with integration of inorganic and organic sources was owing to positive effect of prolonged and adequate supply of nutrients to yield attributes of sweet sorghum crop, viz. plant height, LAI, green leaves and leaf and stem dry weight.

Fodder quality

Application of 75% RDN through inorganic source + 25% through vermicompost + BF recorded significantly higher juice content than the control, 75% RDN through inorganic source + 25% through FYM, 50% RDN through inorganic source + 50% through FYM, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF. The control recorded significantly lower juice content than other treatments. There was non-significant difference in available sugar content between different treatments. Application of 75% RDN through inorganic source + 25% through vermicompost + BF recorded the highest higher dry-matter content, being significantly higher than the control and 75% RDN through inorganic source + 25% through FYM. The control showed significantly lesser dry-matter content than rest of the treatments.

Crude protein content did not influenced significantly by different treatments. The highest digestibility was re-

Table 2. Yield parameters of sweet sorghum as influenced by different nutrient-management treatments

Treatment	Total green fodder yield (t/ha)	Dry-matter yield (t/ha)	Total crude protein yield (t/ha)	Digestible dry-matter yield (t/ha)	Juice yield (kilo litres/ha)	Sugar yield (t/ha)	Calculated ethanol yield (litres/ha)
Control	32.4	7.6	0.53	3.2	5,261	0.49	14,83
RD NPK through inorganic source	49.0	11.9	0.81	5.3	8,669	0.79	2,384
75% RDN through inorganic source + 25% through FYM	45.5	11.0	0.74	5.0	7,890	0.70	2,131
75% RDN through inorganic source + 25% through VC	49.4	12.1	0.83	5.6	8,743	0.80	2,411
50% RDN through inorganic source + 50% through FYM	41.8	10.0	0.74	4.3	6,907	0.63	1,911
50% RDN through inorganic source + 50% through VC	46.1	11.7	0.79	5.1	7,950	0.73	2,197
75% RDN through inorganic source + 25% through FYM + BF	51.3	12.8	0.87	6.2	9,544	0.87	2,641
75% RDN through inorganic source + 25% through VC + BF	52.8	13.5	0.92	6.6	9,910	0.91	2,762
50% RDN through inorganic source + 50% through FYM + BF	46.4	11.4	0.80	5.4	9,068	0.83	2,531
50% RDN through inorganic source + 50% through VC + BF	50.1	12.6	0.89	6.1	9,201	0.85	2,572
33% RDN through inorganic source + 33% through FYM + 33 through VC	43.0	10.5	0.77	4.6	7,290	0.66	1,989
33% RDN through inorganic source + 33% through FYM + 33% through VC + BF	46.3	11.3	0.84	5.0	7,910	0.71	2,151
SEm±	2.0	0.7	0.05	0.4	534	0.05	160
CD (P=0.05)	5.8	2.0	0.15	1.2	1,538	0.15	459

DAS, Days after sowing; RD, recommended dose; RDN, recommended dose of nitrogen; FYM, farmyard manure; BF, biofertilizers; VC, vermicompost corded with the treatment having 75% RDN through inorganic source + 25% through vermicompost + BF and it was superior to control, recommended dose of NPK through inorganic source, 50% RDN through inorganic source + 50% through FYM, 50% RDN through inorganic source + 50% through vermicompost, 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost + BF. The control recorded significantly lesser digestibility than rest of the treatments during both the years.

Treatment having 75% RDN through inorganic source + 25% through vermicompost + BF being at par with recommended dose of NPK through inorganic source, 75% RDN through inorganic source + 25% through vermicompost, 75% RDN through inorganic source + 25% through FYM + BF and 50% RDN through inorganic source + 50% through vermicompost + BF showed significantly higher neutral detergent fibre content than rest of the treatments (Table 3). Application 75% RDN through inorganic source + 25% through vermicompost + BF exhibited significantly higher hemicellulose content than 50% RDN through inorganic source + 50% through FYM, 50% RDN through inorganic source + 50% through vermicompost and 33% RDN through inorganic source + 33% through FYM + 33% through vermicompost.

In general, all the parameters of fodder quality were found higher with 75% RDN + 25% through vermicompost. This treatment resulted in higher sugar yield and it was owing to more juice yield. Saheb *et al.* (1997) while working on sweet sorghum also observed significantly higher stalk yield, juice percentage and juice yield, explaining increasing effect of adequate supply of nutrients both on vegetative growth and succulence of plants. The increase in dry-matter yield under integration of nutrients compared to inorganic sources might be the reason for high crude protein yield under this treatment. High crude protein yield under this treatment might also be due to production of higher metabolizable energy (Kalra and Khokhar, 1979; Krishna *et al.,* 1988).

Soil fertility

There was no significant difference among treatments for available nitrogen and phosphorus (Table 4). The lowest available nitrogen and phosphorus were recorded with the control treatment. The highest available potassium was recorded with the 50% RDN through inorganic source + 50% through vermicompost, being significantly superior to the control, recommended dose of NPK through inorganic source and 75% RDN through inorganic source + 25% through FYM + BF. The control showed significantly lesser available K than rest of the treatments. Higher values of available nitrogen, phosphorus and potassium due to integrated nutrient sources might be a result of buildup in organic carbon, solubilization of simple and available form, acidifying action of FYM/vermicompost on native phosphorus at the time of decomposition making more phosphorus available phosphorus and reduction of potassium fixation (Syed Ismail *et al.,* 1998).

On the basis of 2 years experimentation, it was concluded that application of 75% RDN through inorganic source + 25% through vermicompost + biofertilizer can be

Table 3. Fodder quality parameters of sweet sorghum as influenced by different nutrient-management treatments

Treatment	Juice (%)	Available sugar (%)	Dry-matter content (%)	Crude protein content (%)	Digestibility (%)	Neutral detergent fibre (%)	Hemicellulose (%)
Control	22.0	9.3	23.3	6.5	42.8	53.6	16.9
RD NPK through inorganic source	24.2	9.1	24.4	6.8	44.5	56.8	18.1
75% RDN through inorganic source + 25% through FYM	23.2	9.0	24.0	6.8	45.4	55.8	17.5
75% RDN through inorganic source + 25% through VC	24.2	9.2	24.4	6.9	45.9	57.7	18.8
50% RDN through inorganic source + 50% through FYM	22.2	9.2	24.1	7.0	43.8	53.9	16.4
50% RDN through inorganic source + 50% through VC	23.3	9.2	25.1	6.8	44.1	54.9	16.8
75% RDN through inorganic source + 25% through FYM + BF	25.8	9.2	24.4	6.8	47.5	60.2	20.0
75% RDN through inorganic source + 25% through VC + BF	26.2	9.3	25.6	7.0	48.7	61.0	20.1
50% RDN through inorganic source + 50% through FYM + BF	25.5	9.3	24.9	6.8	47.0	54.2	18.4
50% RDN through inorganic source + 50% through VC + BF	25.1	9.3	25.1	7.0	47.6	59.2	19.1
33% RDN through inorganic source + 33% through FYM + 33 through VC	22.9	9.1	24.3	7.0	43.8	53.5	15.6
33% RDN through inorganic source + 33% through FYM + 33% through VC + BF	23.1	9.1	24.6	7.1	43.6	55.0	16.9
SEm±	1.0	0.4	0.5	0.3	1.3	1.5	1.1
CD (P=0.05)	2.9	NS	1.5	NS	3.7	4.2	3.2

Table 4. Soil fertility parameters after harvesting as influenced by different nutrient management treatments in sweet sorghum

Treatment	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Control	263	24.9	234
RD NPK through inorganic source	279	25.9	244
75% RDN through inorganic source + 25% through FYM	283	27.1	249
75% RDN through inorganic source + 25% through VC	282	26.9	249
50% RDN through inorganic source + 50% through FYM	285	27.4	251
50% RDN through inorganic source + 50% through VC	285	27.2	253
75% RDN through inorganic source + 25% through FYM + BF	284	26.7	247
75% RDN through inorganic source + 25% through VC + BF	284	26.8	249
50% RDN through inorganic source + 50% through FYM + BF	285	27.4	251
50% RDN through inorganic source + 50% through VC + BF	285	27.3	252
33% RDN through inorganic source + 33% through FYM + 33 through VC	287	27.4	251
33% RDN through inorganic source + 33% through FYM + 33% through VC + BF	287	27.6	253
SEm±	13	1.4	2
CD (P=0.05)	NS	NS	5

DAS, Days after sowing; RD, recommended dose; RDN, recommended dose of nitrogen; FYM, farmyard manure; BF, biofertilizers; VC, vermicompost

used for higher fodder productivity and fodder quality in sweet sorghum crop.

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