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Influence of soil and foliar nutrition with different organic and inorganic sources on summer pearlmillet under semi-arid tropics of India

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Abstract
Pearlmillet (*Pennisetum glaucum* L.) is an important drought tolerant hardy millet crop grown in the arid and semi arid regions of the world. In India, Pearlmillet is cultivated in marginal to low fertile sandy or sandy loam soil having nitrogen and phosphorus deficiency, which significantly decreased its productivity. Moreover, response of crops to high nutrient levels in low fertile soil is another constraint which requires more attention due to leaching and volatilization problems. Foliar fertilization along with soil application of nutrients have potential to meet nutrient requirements of crops at critical growth stages and achieving productivity. Therefore, a field experiment was conducted at Demonstration farm, Krushi Vigyan Kendra, Sardarkrushinagar Dantiwada Agricultural University, Deesa, Gujarat during summer season of 2019, 2020 and 2021 to assess the performance of soil and foliar nutrition with different sources on summer pearlmillet. The result revealed that, all the growth traits, yield components, grain and straw yield of summer pearlmillet increased significantly with application of 100% RDF which remained at par with 75% RDF + foliar spray of 2% WSF 19:19:19, 75% RDF + foliar spray of 4% *jivamrut* and 75% RDF + foliar spray of 4% *panchgavya* at 30 & 45 DAS on pooled basis, respectively. Similar trend was also recorded in nitrogen and phosphorous content and uptake of summer pearlmillet. The current study has explored the potential of foliar nutrition along with soil application of nutrients through different organic and inorganic sources.

Keywords: Pearlmillet, foliar nutrition, yield attributes, yield, economics

Introduction
Pearlmillet (*Pennisetum glaucum* L.) is one of the major cereal crops grown in the arid and semi-arid regions of the world. Currently it is grown in India, Pakistan, China, and other south Asian countries. India is the largest producer of pearlmillet, the crop occupies an area of 7.52 million hectares, annual production of 10.28 million tonnes with an average productivity of 1368 kg ha^{-1} during 2019-2020 (DES., 2020) [1]. The area, production and productivity of pearlmillet in Gujarat was 0.41 million hectares, 5.51 million tonnes and 2098 kg ha^{-1}, respectively during 2019-20 (DES., 2020) [1]. Summer cultivation of pearlmillet, particularly in the irrigated areas of North Gujarat has attracted the farmers because of the assurance of targeted crop yield along with fodder for livestock. In the present scenario productivity of pearlmillet in North Gujarat is stagnated due to depleting fertility of soil, poor nutrient use efficiency and uneven use of chemical fertilizers along with excess use of irrigation. Crop productivity and soil health has deteriorated due to less use of organic fertilizer and total reliance on inorganic fertilizer.

Soil application of nutrients is often not enough to meet the growing crop demand particularly in short duration crops. Continuous use of inorganic fertilizers hazards the soil health in respect of physical, chemical and biological properties of soil. The population of beneficial organisms decreases and natural regeneration of nutrition in the soil ceases, causing soil to become barren and infertile. Deteriorating soil fertility with the use of chemical fertilizer threatens the sustainability of agriculture at a global level. Comprehensive studies have shown that full filling partial nutritional requirements of short duration crops through foliar nutrition reduce the chemical load in soil (Minhas *et al*., 2020) [2].

Foliar nutrition is a technique of feeding plants by applying liquid fertilizer directly to the leaves. Plants can absorb essential elements through stomata and epidermis. If used to supplement soil fertilization wisely, it can be more efficient, economical, environment friendly and target oriented. Nowadays, foliar feeding is a widely adopted strategy in modern crop management to ensure optimum crop performance. Foliar application overcomes the limitation of soil application *i.e.* the antagonism between certain nutrients, heterogenic soil unsuitable for low dosages and fixation. This is one of the most efficient ways of supplying essential nutrients to a growing crop. Under existing scenarios, foliar application of mineral nutrients has become an inevitable agricultural practice for sustainable crop production worldwide. "Foliar nutrition" involves the application of any dissolved mineral nutrient directly to the plant foliage (Maheswari and Kartik, 2017) [3]. Foliar fertilization draws attention as a quick, target-oriented, and environmentally compatible insurance to pursue higher crop productivity (White *et al*., 2015 [4]; Malhotra *et al*., 2020 [5]) under optimal and unfavourable growth conditions (Bahrami-Rad and Hajiboland, 2017 [6]; Ruiz-Navarro *et al*., 2019 [7].) As a holistic, foliar nutrition can be widely used to diminish nutritional deficiencies in crop plants at critical growth stages and biofortification of edible plant parts to address malnutrition of micronutrients (Hidoto *et al*., 2017 [8]; Wang *et al*., 2017 [9]). It is also helpful to minimize the soil barriers for higher nutrient use efficiency and advantageous to optimize crop yield, produce quality and reduce environmental concerns, especially nutrients leaching and volatilization losses.

Therefore, it is necessary to minimize the soil application of inorganic fertilizers by adoption of foliar feeding of nutrient in early maturing crops with proper selection of sources of nutrient. Besides, foliar application is credited with the advantage of quick and efficient utilization of nutrients, elimination of losses through leaching and fixation and regulating the uptake of nutrients by plants (Manonmani and Srimathi, 2009) [10]. Foliar spray is effective and requires less amount of fertilizers as compared to soil application. Thus, it is certainly beneficial from a practical point of view. Keeping these points in view, present study was undertaken to assess the influence of soil and foliar nutrition with different organic and inorganic sources on summer pearlmillet under semi-arid tropics of India in sandy loam soil.

Materials and Methods

Location and soil of experimental field plot

The experiment was caried out for three consecutive summer seasons of 2019, 2020 and 2021 at Krushi Vigyan Kendra, Sardakrushinagar Dantiwada Agricultural University, Deesa, Gujarat, India. Site was located at 10.13^o N, 77.59^{o}E at an altitude of 289 m above mean sea level with an average rainfall of 575.0 mm. Before conducting the experiment, composite soil samples were collected from the experimental site at 0-30 cm depth, and the composite sample was prepared and analyzed for physical and chemical characteristics. The initial nutrient status in soil was determined by using the standard procedures. The soil was sandy loam in texture having pH 7.6, low in organic carbon (0.24%) and available nitrogen (138 kg N ha^{-1}), medium in available phosphorus (35.5 kg P_2O_5 ha^{-1}) and available potash (215 kg K_2O ha^{-1}).

Experimental procedure and statistical analysis

The field experiment was carried out in randomized block design with three replications. The treatment comprised of 100% RDF (Control), 75% RDF + foliar spray of 2% urea, 75% RDF + foliar spray of 2% WSF 19:19:19, 75% RDF + foliar spray of 3% cow urine, 75% RDF + foliar spray of 4% *Jivamrut*, 75% RDF + foliar spray of 1% multi micronutrient grade IV, 75% RDF + foliar spray of 4% *Panchgavya* and 75% RDF + foliar spray of 10% vermiwash. Foliar application of nutrients through different sources was carried out at 30 and 45 DAS.

Pearlmillet variety GHB-518 was sown with spacing of 45 × 15 cm spacing with seed rate of 3.75 kg/ha. The recommended dose of fertilizer for summer pearlmillet was 120:60:0 kg NPK ha^{-1}. Observations on growth, yield attributes, yield and nutrient content and uptake were recorded and analysed. Different cow based organic products like *Jivamrut* and *Panchgavya* were prepared at KVK demonstration farm by using ingredients (cow dung, cow urine, cow milk, cow milk curd, cow ghee, coconut water, banana, water and jaggery). The nutrient composition of various organic and bio-enhancers analyzed by standard procedures presented in Table 1. Economics were calculated based on the prevailing market price of the pearlmillet and cost of inputs. Data were analyzed and the standard error of mean SE(m) and critical difference at 5% possibility level (P = 0.05) were calculated as per the formulae (Gomez and Gomez, 1984) [11] to interpret the results.

Result and Discussion

Growth parameters

The data pertaining to plant height of summer pearlmillet at harvest in pooled analysis were significantly influenced by different sources of nutrients through foliar spray are presented in Table 2. Application of 100% RDF (T_1) recorded significantly highest plant height (201.6 cm) of pearlmillet at harvest in pooled analysis. However, it was found to be at par with 75% RDF + foliar spray 2% WSF 19:19:19, 75% RDF + foliar spray of 4% *jivamrut* and 75% RDF + foliar spray of 4% *panchgavya*, respectively. This was mainly because of the increased nutrient supply through foliar feeding and reduced nutrient losses at critical stages of crop growth.

Application of 100% RDF fulfilled the nutrient requirement of pearlmillet and recorded maximum plant height among all the treatments. However, in the case of 75% RDF with a foliar spray of different sources of nutrient like WSF 19:19:19 and liquid cow-based bio-enhancers (*Jivamrut* and *Panchgavya*) recorded at par result with 100% RDF and reduced 25% RDF through foliar sprays. Foliar spray of nutrient through WSF 19:19:19 NPK grade and liquid bio-enhancers (*Jivamrut* and *Panchgavya*) directly absorbed by the plants through stomata and epidermis and helped in easy translocation of nutrient into the plants without any loss that contributed for better photosynthetic activity, which plays a vital role in cell division and growth of the plant and ultimately reflected on significant and quick improvement in crop growth (Malhotra, *et al*., 2020) [5]. Moreover, liquid bio-enhancer applied through foliar spray produce larger cells with thinner cell walls and its contribution in cell division and cell elongation, which promoted vegetative growth and ultimately increased plant height and improved the metabolic and photosynthetic activity for enhancing biological efficiency of plant cause there by accumulation of more carbohydrates and higher dry matter (Upperi *et al*., 2009) [12]. These results corroborate with the findings of Patel *et al*. (2019) [13] and Sharnkumar *et al*. (2012) [14].

Yield attributes and yield

The various yield attributes *viz*., number of effective tillers per plant, length of earhead, girth of earhead, test weight and grain and straw yield of summer pearlmillet were significantly influenced by foliar fertilization through different organic and inorganic sources on polled basis (Table 2). Significantly higher number of effective tillers per plant (2.44), length of earhead (24.59 cm), girth of earhead (10.04 cm), test weight (7.56 g), grain yield (4043 kg ha^{-1}) and straw yield (7144 kg ha^{-1}) of summer pearlmillet were recorded with application of 100% RDF (T_1). However, it was found to be at par with treatment 75% RDF + foliar spray 2% 19:19:19, 75% RDF + foliar spray of 4% *jivamrut* and 75% RDF + foliar spray of 4% *panchgavya*, respectively.

Significant increase in yield attributes, grain and straw yield of summer pearlmillet with foliar nutrition might be due to better availability of nutrients at critical growth stages, have a positive effect on growth parameters like plant height, dry matter production and which might have resulted in better tillering. Foliar application of NPK through WSF 19:19:19 at tillering and flowering stage enhanced root and shoot development by maintaining optimum bio-physiological conditions in plants. Adequate and continuous supply of nutrient through soil and foliar spray promotes the supply of assimilates to sink or yield container, thus enlarging the size of the yield structure (Maheswari *et al*., 2017) [15]. In other treatment, supplementing nutrients through foliar feeding with cow based organic bioenhancers (*Panchagavya* and *Jivamrut*) rich in different macro and micronutrient with beneficial growth hormones, efficient plant growth stimulant enhanced the growth and yield attributes by ensuring prompt delivery of mineral nutrients to the site of photosynthesis and translocated assimilates more efficiently to the developing earhead and further aided for proper grain filling. These results corroborate the findings of Rahman *et al*. (2014) [16], Reddy *et al*. (2018) [17], Patel *et al*. (2019) [13] and Patel *et al*. (2021) [18]. Mannivanan *et al*. (2003) [19] stated that nutrients through foliar spray play an important role in increasing grain yield of the crop through their effect on the plant epidermis, enhance the chlorophyll content, increase the photosynthetic rate, translocation of photosynthates and catalyst for various enzymatic system. The observed improvement in growth and physiological parameters due to basal as well as foliar feeding of nutrients are in close agreement with the findings of Parihar *et al*. (2012) [20] and Zaki *et al*. (2016) [21].

The cumulative effect of improved crop performance with respect to plant height, effective tillers per plant, length of earhead, girth of earhad and test weight contributed to significantly higher grain yield of summer pearlmillet. These results emphasize the full filling the nutrient requirement of crop under the treatments 100% RDF, 75% RDF + foliar spray 2% 19:19:19, 75% RDF + foliar spray of 4% *jivamrut* and 75% RDF + foliar spray of 4% *panchgavya* treatment, obtaining more number of effective tillers, length and girth of earhead and test weight that contribute to higher harvest indices (Table 2), in turn higher grain yield. Our results showed that a close relationship of grain yield of summer pearlmillet was found to be significantly ($P = 0.01$) and positively correlated to various yield attributes (Figure 1). The regression of grain yield on number of effective tillers per plant (0.9743**), length of earhead (0.993**), girth of earhead (0.979**) and test weight (0.937**), respectively. Further, 100% RDF and 75% RDF + foliar fertilization treatments full fill nutrient requirement of crop and observed significant and positive association between grain yield and N grain content in grain (0.950**), N content in straw (0.967**) and total N uptake (0.9924**), respectively (Figure 2).

Nutrient content and uptake

The nutrient-uptake capability of a plant is dependent on availability of each added and inherent source of minerals in the soil, external applied nutrition through foliar spray at critical growth stages, absorption capacity, ramification and distribution of plant roots, which lead to crop. The Present study revealed that nitrogen content in grain and straw and total uptake was significantly highest with the application of 100% RDF (T_1) on pooled basis. However, it was at par with treatment T_3 and T_7 (Table 3). Whereas, phosphorus content in grain was at par with treatment T_3, T_5 and T_7, while phosphorus content in straw and total P uptake recorded at par results with treatment T_3 and T_7. The highest content of nitrogen and phosphorus in grain and straw might be due to application of the recommended dose of N and P full fill the requirement of crop and reflected in their biomass.

Regression of growth traits, yield components and nutrient uptake on grain yield of summer pearlmillet

All the independent variables showed a significant positive and linear relationship with grain yield (Table 4) suggesting an increment in grain yield of summer pearlmillet with increase in given growth trait, yield component and nutrient uptake. However, the magnitude of this reinforcement varied with the independent variable *viz.*, growth trait, yield component, nutrient uptake values and their units. The explained total variation as indicated by coefficient of determination (R^2) in grain yield by various growth traits (plant height, tiller production), yield attributes (length of earhead, girth of earhead and test weight) and nutrient uptake (NP uptake) chosen as independent variables individually ranged from 93.6 to 99.2%. The variance ratio for testing R^2 was highly significant in all the relations. This suggests that the grain yield of summer pearlmillet can be adequately predicted using the tested independent variables *viz.*, growth traits, yield components and nutrient uptake.

Economics

The data presented in table 5 revealed that application of different sources of nutrients through foliar spray affected economics of summer pearlmillet cultivation. Maximum net return value 971.6 US $ ha-1 from pearlmillet was received with treatment T_1 (100% RDF) followed by treatment T_3 (865.2 US $ ha^{-1}) and T_7 treatment (860.7 US $ ha^{-1}). The highest benefit: cost (BCR) 3.02 was obtained with 100% RDF treatment followed by treatment T_5 (2.70).

Table 1: Nutrient compositions of organic sources

Chemical composition	*Panchagavya*	*Jivamrut*	*Vermiwash*	Cow urine
Total N (%)	0.23	0.124	0.11	0.97
Total P (ppm)	185	220	115	53
Total K (ppm)	188	126	154	167

Table 2: Effect of nutrient management treatments on growth parameters, yield attributes, grain and straw yield of summer pearlmillet (pooled data of 3 years)

Treatments	Plant height at harvest (cm)	Effective tillers per plant	Length of earhead (cm)	Girth of earhead (cm)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: 100% RDF (Control)	201.6	2.44	24.59	10.04	7.56	4043	7144
T_2: 75% RDF + foliar spray of 2% urea at 30 & 45 DAS	166.5	2.15	20.37	8.42	6.36	3214	5986
T_3: 75% RDF + foliar spray of 2% 19:19:19 at 30 & 45 DAS	194.5	2.38	23.69	9.61	7.23	3836	6860
T_4: 75% RDF + foliar spray of 3% cow urine at 30 & 45 DAS	165.6	2.16	20.31	8.19	6.25	3233	6038
T_5: 75% RDF + foliar spray of 4% *jivamrut* at 30 & 45 DAS	191.5	2.32	22.70	9.22	7.15	3607	6631
T_6: 75% RDF + foliar spray of 1% multi micro nutrient grade IV at 30 & 45 DAS	175.1	2.24	21.09	8.67	6.71	3383	6334
T_7: 75% RDF + foliar spray of 4% *panchgavya* at 30 & 45 DAS	196.4	2.36	23.79	9.91	7.27	3876	6868
T_8: 75% RDF + foliar spray of 10% vermiwash at 30 & 45 DAS	172.0	2.21	20.79	8.56	6.67	3318	6264
SEm+	5.36	0.05	0.76	0.25	0.18	151	165
CD (P=0.05)	15.11	0.14	2.31	0.70	0.50	457	466
CV (%)	10.15	7.95	9.27	9.68	9.18	11.20	9.28

Table 3: Effect of nutrient management treatments on content and uptake of N and P by summer pearlmillet (pooled data of 3 years)

	N content (%)		P content (%)		Total uptake (kg ha^{-1})	
Treatment	Grain	Straw	Grain	Straw	Total N	Total P
T_1: 100% RDF (Control)	1.370	0.455	0.528	0.209	88.24	36.40
T_2: 75% RDF + foliar spray of 2% urea at 30 & 45 DAS	1.121	0.363	0.449	0.176	57.76	25.02
T_3: 75% RDF + foliar spray of 2% 19:19:19 at 30 & 45 DAS	1.296	0.436	0.506	0.201	80.13	33.53
T_4: 75% RDF + foliar spray of 3% cow urine at 30 & 45 DAS	1.066	0.347	0.438	0.173	55.48	24.73
T_5: 75% RDF + foliar spray of 4% *jivamrut* at 30 & 45 DAS	1.256	0.421	0.491	0.192	73.21	30.44
T_6: 75% RDF + foliar spray of 1% multi micro nutrient grade IV at 30 & 45 DAS	1.184	0.391	0.478	0.183	64.82	27.87
T_7: 75% RDF + foliar spray of 4% *panchgavya* at 30 & 45 DAS	1.345	0.442	0.519	0.206	82.66	34.25
T_8: 75% RDF + foliar spray of 10% vermiwash at 30 & 45 DAS	1.156	0.380	0.465	0.181	62.18	26.83
SEm$\pm$	0.028	0.010	0.014	0.005	3.90	1.56
CD (P=0.05)	0.086	0.03	0.041	0.015	11.84	4.75
CV (%)	4.82	4.95	4.50	4.47	8.89	8.68

Table 4: Empirical estimates for the regression of growth traits, yield components and nutrient uptake on grain yield of pearlmillet (Pooled basis)

Relationship	Regression constant, coefficients and test statistics				
	a	b	SEb	R^2	F value for testing R^2
Yield – Plant height (cm)	-399.821	21.670	1.80	0.960**	144.67
Yield – No. of effective tillers per plant	-3175.9	2952.7	195.7	0.974*	227.6
Yield –length earhead (cm)	-564.25	186.229	6.393	0.992*	848.1
Yield – Girth of earhead (cm)	-488.08	446.36	26.66	0.979*	280.3
Yield – Test weight (g)	-1017.9	664.1	70.31	0.936**	89.18
Yield – N uptake (kg ha^{-1})	1717.1	26.17	1.08	0.983*	585.6
Yield – P uptake (kg ha^{-1})	1404.6	72.25	2.13	0.994*	1150.4

Table 5: Effect of nutrient management treatments on economics of summer pearlmillet

Treatments	Cost of cultivation (US $ ha^{-1})	Gross return (US $ ha^{-1})	Net return (US $ ha^{-1})	BCR
T_1: 100% RDF (Control)	480.7	1452.3	971.6	3.02
T_2: 75% RDF + foliar spray of 2% urea at 30 & 45 DAS	485.2	1174.1	688.9	2.42
T_3: 75% RDF + foliar spray of 2% 19:19:19 at 30 & 45 DAS	518.0	1383.2	865.2	2.67
T_4: 75% RDF + foliar spray of 3% cow urine at 30 & 45 DAS	491.5	1182.1	690.5	2.40
T_5: 75% RDF + foliar spray of 4% *jivamrut* at 30 & 45 DAS	485.2	1312.1	826.9	2.70
T_6: 75% RDF + foliar spray of 1% multi micro nutrient grade IV at 30 & 45 DAS	525.9	1237.9	712.0	2.35
T_7: 75% RDF + foliar spray of 4% *panchgavya* at 30 & 45 DAS	532.9	1393.6	860.7	2.62
T_8: 75% RDF + foliar spray of 10% vermiwash at 30 & 45 DAS	496.8	1217.4	720.6	2.45

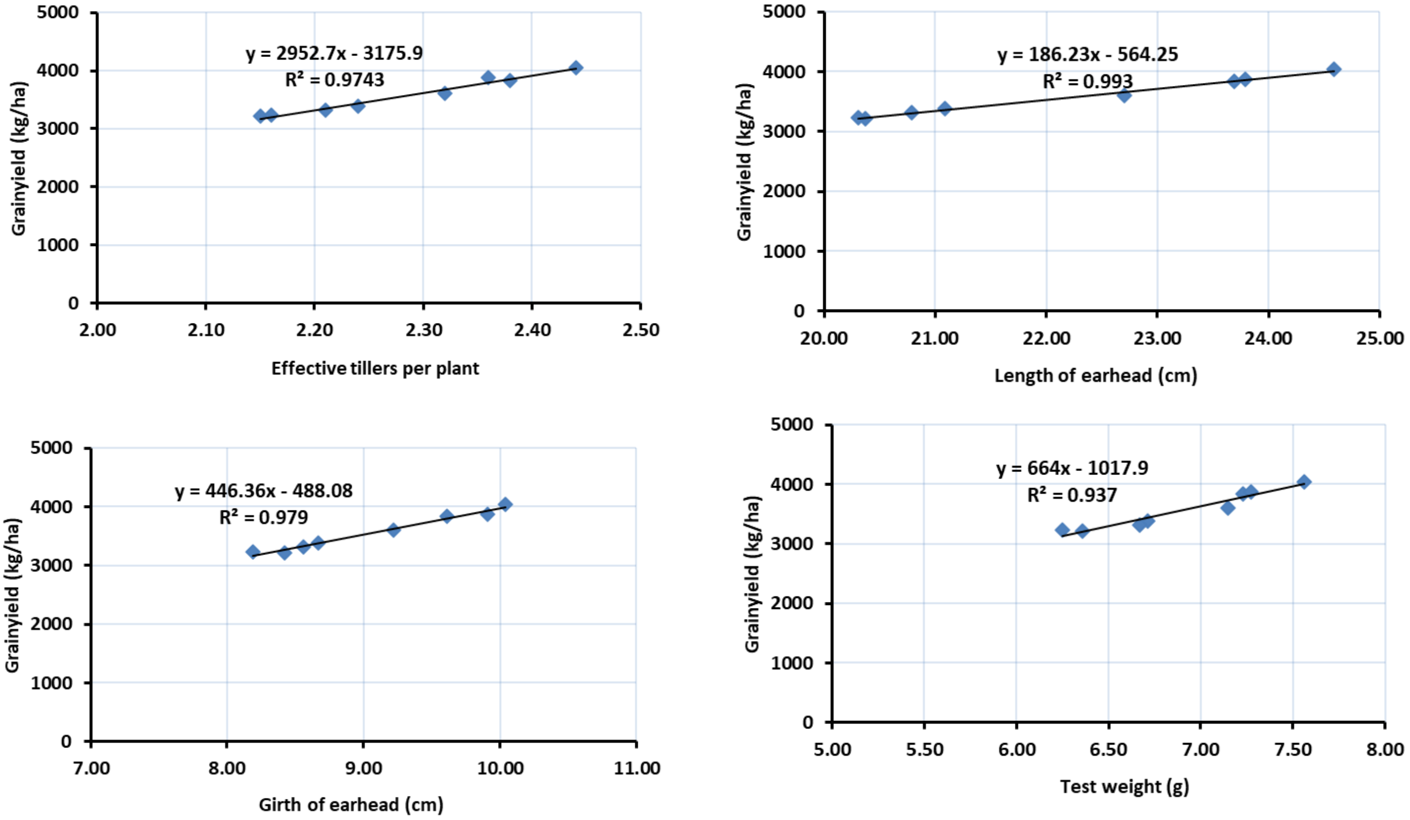

Fig 1: Regression of summer pearlmillet grain yield versus number of effective tillers per plant, length of earhead, girth of earhead, test weight

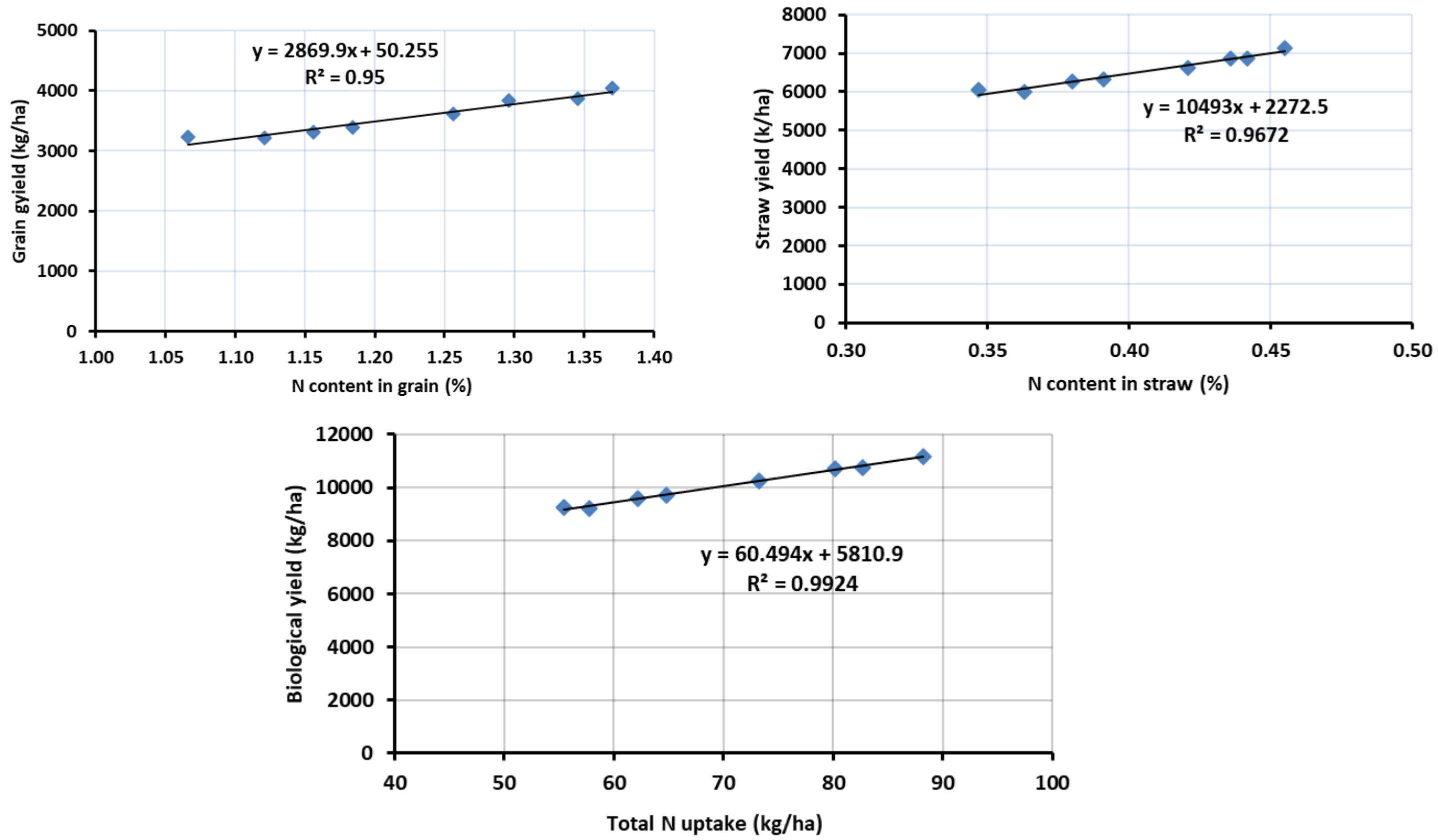

Fig 2: Regression of summer pearlmillet grain yield versus N content in grain and straw and total N uptake

Conclusion

Our result provided valuable insight indicating that foliar fertilization with organic and inorganic sources at critical growth stages along with soil application of nutrients achieved yield equivalent to 100% RDF. Foliar nutrition of 2% WSF 19:19:19 or 4% *jivamrut* or 4% *panchgavya* at 30 and 50 DAS along with 75% RDF is more compatible from a sustainable agriculture point of view. Means with 25% load of chemical fertilizer is soil can be abridged with foliar fertilization at critical growth stages in short duration high nutrient demanded crops like pearlmillet.

Conflict of Interest

The author declares no potential conflict of interest.

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