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Srinivasa DK
SRF, Department of Soil Science and Agricultural Chemistry, College of Agriculture, GKVK, UAS, Bengaluru, Karnataka, India

Chikkaramappa T
Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, GKVK, UAS, Bengaluru, Karnataka, India

Sukanya TS
Agronomist, Project Coordinating Unit, AICRP on Small Millet, ZARS, GKVK, UAS, Bengaluru, Karnataka, India

Murali K
Professor, Department of Agronomy, College of Agriculture, GKVK, UAS, Bengaluru, Karnataka, India

Corresponding Author:
Srinivasa DK
SRF, Department of Soil Science and Agricultural Chemistry, College of Agriculture, GKVK, UAS, Bengaluru, Karnataka, India

Enhancing growth and yield potential of foxtail millet through potassium application in eastern dry zone of Karnataka

Srinivasa DK, Chikkaramappa T, Sukanya TS and Murali K

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Abstract
As we know that intensive cropping with high yielding varieties makes considerable demand on the soil nutrients and application of nitrogen alone is not a prescription to obtain higher yields without other nutrients supplement. The red soils of Southern Karnataka are natively rich in potassium, hence potassium is not recommended for foxtail millet in Eastern Dry Zone of Karnataka. However, long-term intensive cropping without its application resulted in low to medium status and reduced potassium supply to crop plants and consequently crop yields. By considering nutritional aspects, different levels of potassium have been applied to foxtail millet. Totally twelve treatments were tested which includes absolute control, recommended dose of fertilizers as per UAS, Bangalore package (40:40:0 kg N, P_2O_5 and K_2O per hectare, same level of nitrogen, phosphorus and 10, 20, 30, 40 and 50 kg of potassium, 50 kg nitrogen, 45 kg phosphorus, 10, 20, 30, 40 and 50 kg of potassium. These treatments were replicated thrice using RCBD. The initial soil was low in potassium (119.84 kg ha^{-1}), neutral in reaction (6.59), low organic carbon (0.47%), low available nitrogen (136.42 kg ha^{-1}), phosphorus (16.62 kg ha^{-1}) and sandy loam in texture. From the experiment it was clear that, application of 40 kg nitrogen, 40 kg phosphorus and 40 kg potassium along with 7 tonnes of FYM is performed well by recording highest plant height, number of tillers, panicle length, panicle weight, grain yield and straw yield. Application of increased levels of potassium significantly increased the yield potential of the foxtail millet.

Keywords: potassium, foxtail millet, graded levels and yield potential

Introduction
Foxtail millet is the principal crop of southern states of the India but its productivity is very poor in respect of its desirable level. This states are the major contributors to the country's foxtail millet production. Foxtail millet is the second most widely grown species of millet and the most important food crop in East Asia. In India, foxtail millet is important crop in arid and semi-arid regions. In South India, it is a staple diet among people for a long time and it is a warm season crop, typically grown in late spring season and harvest of grain in 75-90 days (800-900 kg ha^{-1}). In India, Andhra Pradesh (4,79,000 ha), Karnataka (2,32,000 ha) and Tamilnadu (20,000 ha) are the major foxtail millet growing states contributing about 90 per cent of the total area under cultivation. Andhra Pradesh is a major foxtail millet growing state contributing more than 59 per cent of the total area (Anbukkani *et al*., 2017) [1]. Regions with low average yield of foxtail millet compared to other millets put forward an urgent requirement of balanced application of nutrients which includes the four basic principles i.e. right time, right rate, right source and right method that would ensure higher economic return with environmental balance (Majumdar *et al*., 2012) [12]. The recommended dose of fertilizer application is now showing signs of fatigue in the cropping systems as negative balance of the primary nutrients particularly for potassium. Potassium content in Indian soil varies from < 0.5% to 3.0%, average being 1.52% (Mengel and Kirkby, 1987) [13]. It performs several functions by activating more than 72 enzymes but its recommendation for cereals, millets and pulses are often far lower than that removed by the crops, whereas the modern high-yielding varieties remove much higher amount of potassium than phosphorus and nitrogen from the soil. Low external application of potassium followed by common practice of removing crop residues from fields have led to its depletion in soil (Timsina *et al*., 2013) [17].

Despite of the fact that potassium accounts for a greater share of total nutrients removed from the soil by crops, the application of potassium to foxtail millet is not recommended and has received least attention.

As a result, Indian soils are being continuously mined of their available potassium reserve, its removal is much higher compared to replenishment. Potassium mining and depletion of soil potassium reserves pose a greater threat to Indian agriculture which may affect crop productivity, soil health and environmental quality (Kurbah *et al*., 2017) [10]. Balanced fertilization of NPK has shown better yield of finger millet in comparison to NP use only under finger millet – ground nut cropping sequence field experiments for two years from 2014 -2016 (Prashantha, 2018) [14]. Though, basal application was able to meet the demand of early vegetative growth but it could not satisfy the demand of crops at the later phases of growth or at harvest. There is an urgent need to educate farmers about the importance of K in Indian agriculture for nutrient balance and efficiency. Keeping this view in mind, this experiment was conducted to evaluate the optimum level of potassium application on growth and yield of foxtail millet during *kharif* 2016 and 2017 to supply of potassium to the plants at every important growth and developmental stage where they require more nutrients so that plants will never feel lacking of potassium and will be able to give higher yield with minimum losses. The main objective of this experiment was to find the optimum level of potassium application on growth and yield of foxtail millet.

Material and methods

Experimental site

The field experiment was carried out at farmer's field of Devapalli village, Chintamani taluk, Chikkaballapura district, Karnataka during kharif 2016 and 2017 to enhance the growth and yield of foxtail millet with the application of potassium. The experimental site is located at Eastern dry zone of agro climatic zone – 5 of Karnataka between 78º 18' 20.2" E longitudes and 13º 56' 57.8" N latitudes above MSL. The soil was sandy loam in texture, neutral in reaction (6.59), low organic carbon (0.47%), low available nitrogen (136.42 kg ha^{-1}), phosphorus (16.62 kg ha^{-1}) and potassium (119.84 kg ha^{-1}) and medium in available sulphur (19.69 mg kg^{-1}).

Experimental details

Treatments comprised of five levels of potassium application *i.e*. 10, 20, 30,40 and 50 kg of K_2O ha^{-1}, the treatments are absolute control (T_1), RDF (40:40:0 N, P_2O_5: K_2O and 6 tonnes of FYM) as per UAS, Bangalore package (T_2), recommended N P_2O_5 + 10 kg K_2O ha^{-1}(T_3), recommended N P_2O_5 + 20 kg K_2O ha^{-1}(T_4), recommended N P_2O_5 + 30 kg K_2O ha^{-1}(T_5), recommended N P_2O_5 + 40 kg K_2O ha^{-1}(T_6), recommended N P_2O_5 + 50 kg K_2O ha^{-1}(T_7), 50 kg N + 45 kg P_2O_5 + 10 kg K_2O ha^{-1}(T_8), 50 kg N + 45 kg P_2O_5 + 20 kg K_2O ha^{-1}(T_9), 50 kg N + 45 kg P_2O_5 + 30 kg K_2O ha^{-1}(T_{10}), 50 kg N + 45 kg P_2O_5 + 40 kg K_2O ha^{-1}(T_{11}), 50 kg N + 45 kg P_2O_5 + 50 kg K_2O ha^{-1}(T_{12}) and farm yard manure was common for all treatments except absolute control. Three replications laid out in randomised complete block design with a net plot size of 4.2 m × 4 m. Foxtail millet cv. SiA-3156 was grown as a test crop during *kharif* seasons of 2016 and 2017. It is a medium duration variety that attains maturity in 85 -90 days and is pure line from 2871, developed by RARS, Nandyal, ANGRU during 2012 for the Karnataka, Andhra Pradesh, Tamil Nadu, Bihar, Gujarat, Madhya Pradesh and Uttarakhand and sowing period from July to August under irrigated conditions. It is highly responsive to nitrogenous fertilizers with 6-9 productive tillers with long and dropping ear heads. Ear heads has high grain density with yellow colour grains. The average grain yield of the variety is 15-20 q ha^{-1} with a seed rate of 7-10 kg ha^{-1}. The plots were prepared, calculated amount of FYM is applied and recommended dose of fertilizers were applied in the form of urea (N), single super phosphate (P_2O_5) and muriate of potash (K_2O) as per the calculated amount to each plot. Protective irrigation was provided to fulfil crop requirement as per the need of the crop and two hand weeding at 25 and 45 days after sowing (DAS) were done to reduce crop-weed competition, no herbicide was used for weed control. Harvesting and threshing operations were done manually by separating each plot with the help of sickles and crop was sun-dried before threshing after that straw and grain of each plots were weighed and tagged separately.

Results and discussion

Effect on plant height

Plant height increased significantly at 30 DAS to harvest of the crop (table 1). Potassium application with T_6 treatment showed better plant height at all growth stages followed by T_{11} treatment. Marked increase in plant height was observed with increase in the levels of potassium from 10 to 50 kg ha^{-1}. Treatment T_6 recorded highest plant height 54.13 cm, 127.39 cm and 131.80 cm at 30 DAS, 60 DAS and at harvest respectively, which was statistically at par with T_{11} treatment and least values were recorded in absolute control (T_1). Higher plant might be due to regulated and higher dose of potassium applied which increased its uptake by plant as 75% of the total K uptake and the remaining even before the grain formation begins as stated by Ravichandran (2011) in rice crop. The taller plants observed in potassium applied treatments along with nitrogen and phosphorus might be due to increased activity of meristematic cells and cell elongation thus increasing the plant height. In soils with low potassium content, it is expected that the millets respond expressively to application of K fertilizer. Some studies have highlighted the importance of potassium fertilization on the foxtail millet crop, emphasizing its effect on development, nutrition and production (Sharma *et al*., 2011 and Lobo *et al*., 2012) [16, 11].

Table 1: Effect of different levels of potassium on plant height of foxtail millet

Treatments	Plant height (cm)								
	30DAS			60DAS			Harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	38.45	32.45	35.45	104.19	89.93	97.06	107.04	97.80	102.42
T_2	52.41	36.25	44.33	115.49	98.45	106.97	120.73	106.89	113.81
T_3	54.49	36.58	45.54	117.95	102.11	110.03	123.07	106.83	114.95
T_4	54.73	38.21	47.11	117.40	102.95	110.17	123.40	108.85	116.12
T_5	56.56	39.48	47.39	124.79	107.65	116.22	126.79	109.56	118.18
T_6	63.48	44.79	54.13	138.47	116.32	127.39	138.92	124.68	131.80

T_7	59.26	40.23	49.75	130.67	111.68	121.18	132.74	116.93	124.84
T_8	56.81	37.51	47.16	119.49	102.13	110.81	122.18	108.87	115.53
T_9	57.07	39.03	48.05	123.29	99.59	111.44	125.37	112.21	118.79
T_{10}	58.01	40.31	49.16	128.67	102.99	115.83	129.77	119.40	124.59
T_{11}	61.92	44.77	53.35	132.95	115.44	124.20	137.77	120.85	129.31
T_{12}	59.02	42.76	50.89	137.60	104.05	120.83	133.10	119.54	126.32
SE.m ±	2.66	1.33	1.64	2.69	2.25	1.55	3.09	2.49	2.32
CD @ 5 %	7.79	3.90	4.81	7.90	6.60	4.54	9.05	7.30	6.81

Effect on number of tillers hill^{-1}

Data on number of tillers per m^2 showed a progressive increase upto crop harvest. Significantly higher number of tillers was recorded in the T_6 (3.47) which was on par with T_{11} with 3.27 tillers hill^{-1}. However, least number of tillers hill^{-1} (1.47) was recorded in absolute control (T_1). Application of graded levels of potassium gave significantly superior results on number of tillers hill^{-1} as compared to without potassium in RDF. Highest number of tillers was in T_6 because of the continuous supply of potassium to the crop at different growth phases which was proved more beneficial for the increase in the total number of tillers per hill. Potassium plays a crucial role in meristematic growth through its effect on synthesis of phyto-hormones. Among various plant hormones, cytokinin plays an important role in growth of tillers and buds (Yadav *et al*. 2012) [18].

Effect on yield attributing characters

Important yield parameters of foxtail millet are panicle length and panicle weight which were recorded in present. The final grain yield obtained in a crop is a manifestation of the crop growth and development which is demonstrated through the different yield attributing characters. All yield attributes (table 2) marked significant increase under T_6 over T_1 but they were statistically at par with T_{11}. The function of potassium in increasing assimilating power and better translocation efficiency resulted in the expression of better yield attributes in the form of effective tillers m^{-2}, panicle length, grains per panicle (Arivazhagan and Ravichandran, 2005) [2].

It is apparent from the data (Table 2) that there was a significant increase in panicle length with increase in potassium levels up to 40 kg K_2O ha^{-1}, which was on par with 50 kg K_2O ha^{-1}. Application of T_6 registered a panicle length of 20.25 cm which was on par with T_{11} (19.60 cm), T_7 (18.40 cm) and T_{12} (18.39 cm). The potassium applied treatments recorded significantly higher panicle length as compared to the application of RDF (T_2, 14.32 cm). Panicle length was lowest in the absolute control (T_1:11.13 cm). The panicle weight was significantly increased with the application of recommended N, P_2O_5 + 40 kg K_2O ha^{-1} (T_6: 9.64 g plant^{-1}) and was on par with T_{11} (9.15 g plant^{-1}) as compared to (T_2) POP of UAS (B) (5.57 g plant^{-1}) and the lowest panicle weight was recorded in T_1 (4.52 g plant^{-1}) (Table 2). Banerjee *et al*. (2018) [5] also reported that increase in total photosynthetic rate and net assimilation rate at heading and maturing stages with high K application might have led to greater dry matter production and effective tillers. Higher yield by the application of graded levels of potassium might be due to enhanced grain weight which was the result of delay in abscisic acid (ABA) peak by four to five days causing delayed maturation and increased carbohydrate translocation to the seeds. Results of the study are in agreement with the findings of Islam *et al*. (2015) [8] in rice with the application of potassium.

Table 2: Effect of different levels of potassium on yield attributes of foxtail millet

Treatments	Yield attributes								
	Number of tillers			Panicle length (cm)			Panicle weight (g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	1.40	1.53	1.47	11.23	11.03	11.13	4.48	4.57	4.52
T_2	2.43	1.67	2.05	15.53	13.10	14.32	6.26	4.88	5.57
T_3	2.53	2.00	2.27	16.60	14.23	15.42	6.48	6.39	6.44
T_4	2.73	2.47	2.60	17.07	15.69	16.38	7.82	7.14	7.48
T_5	3.00	3.20	3.10	19.63	14.15	16.89	8.05	7.68	7.87
T_6	3.33	3.60	3.47	22.11	18.39	20.25	10.03	9.26	9.64
T_7	3.13	2.93	3.03	20.08	16.71	18.40	8.44	8.37	8.40
T_8	2.47	2.20	2.33	16.36	15.00	15.68	8.28	6.55	7.42
T_9	2.80	2.20	2.50	17.70	16.15	16.93	8.41	7.62	8.01
T_{10}	2.93	2.27	2.60	18.73	16.12	17.43	8.48	7.93	8.21
T_{11}	3.27	3.27	3.27	21.10	18.09	19.60	9.79	8.50	9.15
T_{12}	3.17	3.00	3.08	19.13	17.65	18.39	8.83	8.12	8.47
SE.m ±	0.21	0.15	0.13	0.65	0.74	0.51	0.39	0.21	0.24
CD @ 5 %	0.62	0.45	0.38	1.91	2.17	1.49	1.14	0.61	0.70

Effect on dry matter accumulation

Dry matter production is the net outcome of photosynthetic efficiency of any crop plant. It accumulates in different parts of plant including grains which has a direct positive effect on grain yield. The dry matter accumulation gradually increases with the age of crop. In present experiment, dry matter accumulation (g plant^{-1}) was increased under T_6 at all the growth stages of the foxtail millet crop *ie*.13.82g plant^{-1}, 17.57g plant^{-1} and 28.01 g plant^{-1} at maximum tillering stage (45 DAS), panicle initiation stage (60 DAS) and at harvest (120 DAS), respectively, which were found significantly superior over other treatments (table 3). Application of potassium registered significantly superior effect over without potassium application with respect to dry matter accumulation (g plant^{-1}) in context of all the levels of applied potassium and the maximum dry matter was accumulated under T_6while its lowest value was received in case of absolute control (T_1). The application of potassium controlled the opening and closing of stomata and promoted better photosynthetic activities resulting into higher dry matter production. Similar result of increased dry matter production with increased level of potassium was also reported by Karanam *et al*. (2016) [9] and Banerjee *et al*. (2018) [5].

Table 3: Effect of different levels of potassium on dry matter production of foxtail millet

Treatments	Dry matter production								
	Maximum tillering stage 45 DAS (g plant^{-1})			Panicle initiation stage 60 DAS (g plant^{-1})			Harvest 120 DAS (g plant^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	9.17	9.60	9.39	11.56	12.24	11.90	14.98	15.85	15.41
T_2	11.12	11.78	11.45	14.11	12.90	13.50	18.50	16.80	17.65
T_3	11.57	12.22	11.90	14.41	13.28	13.84	19.22	18.07	18.64
T_4	11.92	12.56	12.24	14.64	13.59	14.11	20.29	20.36	20.32
T_5	12.11	13.20	12.66	14.71	14.35	14.53	23.92	22.86	23.39
T_6	13.63	14.00	13.82	17.83	17.31	17.57	29.41	26.60	28.01
T_7	12.18	13.00	12.59	16.47	15.22	15.84	24.06	24.40	24.23
T_8	11.51	11.95	11.73	12.49	13.51	13.00	22.85	19.81	21.33
T_9	11.61	12.22	11.92	14.85	13.44	14.15	23.93	21.23	22.58
T_{10}	11.88	13.19	12.53	16.21	14.04	15.12	24.19	23.19	23.69
T_{11}	12.55	13.63	13.09	17.10	16.93	17.01	26.48	25.61	26.04
T_{12}	11.82	12.90	12.36	16.89	14.74	15.82	24.79	24.81	24.80
SE.m ±	0.25	0.31	0.21	0.54	0.43	0.38	1.25	0.70	0.74
CD @ 5 %	0.73	0.92	0.61	1.59	1.28	1.13	3.68	2.05	2.16

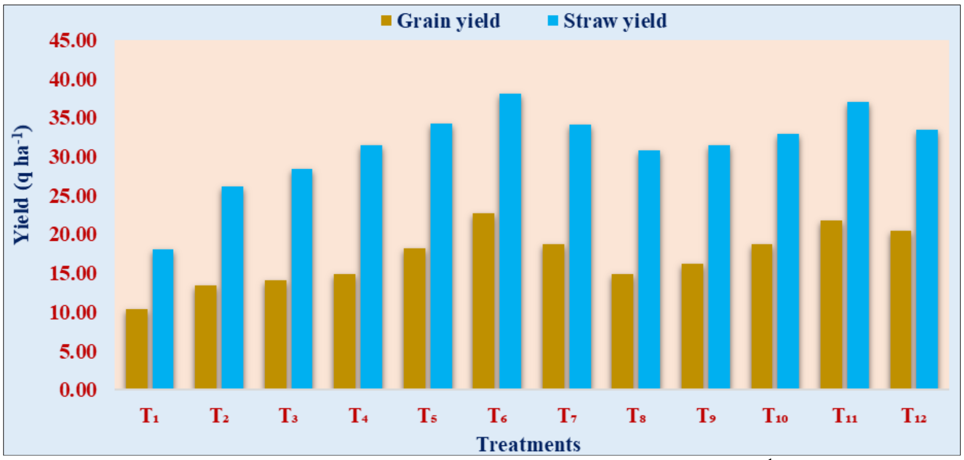
Effect on grain yield and straw yield

In present experiment among the different levels of potassium, highest grain (22.66 q ha^{-1}) and straw yield (38.15 q ha^{-1}) were obtained for T_6, application of recommended N, P_2O_5 + 40 kg K_2O ha^{-1}, which was on par with T_{11} (21.76 and 37.05 q ha^{-1} of grain and straw yield) as compared to RDF as per UAS (B) package of practice (T_2) which recorded 13.38 q ha^{-1} of grain and 26.15 q ha^{-1} of straw yield (Table 4). The lowest grain yield (10.38 q ha^{-1}) and straw yield (18.03 q ha^{-1}) was noticed in the absolute control (T_1). High rate of potassium application helped to produce large amount of starch due to K-mediated carbohydrate metabolism, which performed efficient translocation of photo-assimilates to the developing fingers which directly helped in increasing the grain yield and straw yield. Similar findings were also reported by Ashiana *et al*. (2017) [3] and Charate *et al*. (2018) [6].

As potassium plays a vital role in synthesis of amino acids and protein from the ammonical nitrogen absorbed from soil and also enhances the uptake of nitrate and its assimilation to protein efficiently and promotes better translocation of carbohydrate from source to sink resulting into high grain and straw yield with increased level of potassium (Baehkaiya *et al*., 2007) [4]. Potassium application increases the cytokinin synthesis and photosynthates, which ultimately increases the grain yield of foxtail millet. Application of higher doses of K showed the significant difference in 2 years experiment but application of 50 kg K_2O ha^{-1} has no effect over the 40 kg K_2O ha^{-1}. From the present experiment, it is cleared that application of 40: 40: 40 kg N, P_2O_5 and K_2O ha^{-1} increased the yield of foxtail millet as compared to only NP. Similar results were noticed by Ramachandrappa *et al.* (2013) [15] where application of recommended N, P_2O_5 and 150 per cent recommended K (50: 40: 37.5 kg ha^{-1}) to finger millet has increased the mean grain and straw yields as compared to treatments having no K application. Treatments of potassium application are registered significant effect on Harvest index and the results obtained by Esfahani *et al*. (2005) [7] also justify it.

Table 4: Effect of different levels of potassium application on yield parameters in foxtail millet

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest Index		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	10.67	10.08	10.38	18.50	17.56	18.03	0.37	0.36	0.37
T_2	13.34	13.42	13.38	27.45	24.86	26.15	0.33	0.35	0.34
T_3	13.68	14.49	14.08	29.41	27.47	28.44	0.32	0.35	0.33
T_4	14.09	15.82	14.96	31.46	31.49	31.48	0.31	0.33	0.32
T_5	17.82	18.64	18.23	32.80	35.82	34.31	0.35	0.34	0.35
T_6	22.25	23.07	22.66	37.78	38.52	38.15	0.37	0.36	0.38
T_7	18.21	19.19	18.70	33.25	34.98	34.12	0.35	0.35	0.35
T_8	14.68	15.07	14.88	30.74	30.96	30.85	0.32	0.33	0.32
T_9	15.12	17.29	16.20	31.73	31.18	31.45	0.32	0.36	0.34
T_{10}	17.40	20.07	18.73	32.31	33.63	32.97	0.35	0.37	0.36
T_{11}	21.20	22.31	21.76	36.92	37.18	37.05	0.36	0.37	0.37
T_{12}	19.97	20.90	20.44	32.94	33.95	33.44	0.38	0.36	0.37
SE.m ±	0.73	0.61	0.52	0.98	0.89	0.66	0.01	0.01	0.01
CD @ 5 %	2.14	1.79	1.51	2.88	2.62	1.92	0.04	0.03	0.03



T_1: Absolute control
T_2: POP based on UAS (B) package
T_3: Rec. N P_2O_5+ 10 kg K_2O ha^{-1}
T_4: Rec. N P_2O_5 + 20 kg K_2O ha^{-1}
T_5: Rec. N P_2O_5 + 30 kg K_2O ha^{-1}
T_6: Rec. N P_2O_5 + 40 kg K_2O ha^{-1}
T_7: Rec. N P_2O_5 + 50 kg K_2O ha^{-1}
T_8: 50 kg N + 45 kg P_2O_5 + 10 kg K_2O ha^{-1}
T_9: 50 kg N + 45 kg P_2O_5 + 20 kg K_2O ha^{-1}
T_{10}: 50 kg N + 45 kg P_2O_5 + 30 kg K_2O ha^{-1}
T_{11}: 50 kg N + 45 kg P_2O_5 + 40 kg K_2O ha^{-1}
T_{12}: 50 kg N + 45 kg P_2O_5 + 40 kg K_2O ha^{-1}

Fig 1: Effect of different levels of potassium on grain and straw yield (q ha^{-1}) of foxtail millet

Conclusion

Including the potassium in RDF along with improved K management practices like appropriate dose, method, time and split application of potassium in foxtail millet is essential for increasing the yield. Based on two year of experiment it can be concluded that increased dose of potassium (40 kg K ha^{-1}) may be recommended for profitable foxtail millet cultivation because of its role in developing stronger assimilating source *viz*. plant height, dry matter accumulation and efficient sink in terms of higher number of effective tillers, panicle length resulting in higher grain and straw yield of foxtail millet in dry land situation with the protective irrigation along with 40 kg nitrogen, 40 kg phosphorus and FYM. An uninterrupted supply of potassium needed during the entire crop growth period to enhance the growth parameters, yield attributes and consequently final yield. Potassium should be applied along with nitrogen and phosphorus to increase the potassium availability at different stages of growth and for balanced growth and maximum yields. The result confirms that the present recommended level (40 kg N, 40 kg P_2O_5, 0 kg K_2O along with 6 tonnes of FYM ha^{-1}) is inadequate to support attainable yield potentials of foxtail millet in present situation. A rate of 40 kg K_2O ha^{-1} may be recommended to achieve higher productivity of foxtail millet under dry land situation with protective irrigation in eastern dry zone of Karnataka.

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