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Yield and Qualitative Evaluation of Fodder Maize (*Zea mays* L.) under Potassium and Zinc based Integrated Nutrient Management

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ABSTRACT

Nutritional deficiency, including that potassium and zinc, is one of the critical factors that hinder the quality fodder production in India, which can only be solved with integrated nutrient management approach. This experiment was conducted during the *Kharif* season of 2019 to find out the effect of potassium, zinc, plant growth-promoting rhizobacteria (PGPR) and farmyard manure (FYM) application to the quality aspect of fodder maize. The experiment was conducted in Randomized Block Design (RBD) with nine treatments with standard (100%) and reduced (75%) rate of the recommended dose of potassium (RDK) along with inclusion and exclusion of zinc foliar spray, PGPR and FYM. The experiment results revealed that application of 100 % RDK+PGPR+ YM (5 t ha^{-1}) + two-time spray of 0.5% Zn resulted in higher green fodder yield (t ha^{-1}), dry fodder yield (t ha^{-1}), dry matter and ash content, increased crude protein (CP) content and yield with a concomitant decrease in fibre fractions over other treatments and control. The conclusion from the experiment can be drawn that the combined application of potassium, zinc, PGPR and FYM can result in quality production of fodder maize.

Key words: Fodder Maize, Potassium, Quality, Yield, Zinc

INTRODUCTION

Agriculture plays a crucial role to provide bread and butter to more than half of the population of India despite its falling contribution to India's GDP (Sasmal, 2016). Among different enterprises under the giant umbrella of the agricultural production system; livestock is the most prominent one. According to the 19th livestock census; India has a livestock population of 512.06 million, which is the largest in the world (Anonymous, 2018). This sizeable livestock population plays a multitude of roles of ensuring food security, poverty alleviation, evading climate change and engaging women in agriculture in a large number (Ali, 2007; Gill and Smith, 2008; Smith *et al.,* 2013; Patel *et al.,* 2016). Despite India's large livestock population and its global position with highest milk production (176.35 million tonnes in 2018-19); the productivity of Indian cattle is low compared to the global average and even lower than the European countries (Rajendran and Mohanty, 2004; Pratap and Jha, 2005). The reason can be different; from improper and inadequate nutrition to breeding and lack of adaptability problem (Pratap and Jha, 2005). Lack of quantity and quality in green fodder is one of the prime factors which is holding back the higher production of dairy animals throughout India (Patil *et al.,* 2009; Nagrale *et al.,* 2015; Gupta *et al.,* 2019). The problem can only be solved by high yielding quality fodder production, such as maize with proper agronomic practices.

Maize is one of the most prominent forage crops not only in India but throughout the world owing to its higher growth rate and yield, wider adaptability, higher digestibility, more palatability and lack of any potential anti-nutritional factor (Hedayetullah and Zaman, 2018). On the dry weight basis, average nutritional content in fodder maize is 20.5-24.7% dry matter (DM), 5.5-8.7% crude protein (CP), 23.1-30.2% crude fibre (CF), 64. 1-72.8% neutral detergent fibre (NDF), 38.3-46.8% acid detergent fibre (ADF) and 6.0-8.0% ash (Chaudhary *et al.,* 2011). However; the optimum quantity and quality of maize fodder production depend upon several factors; among which time of sowing, adequate moisture availability and sufficient supply of all essential macro- and micro-nutrient to the plant comes

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in the first place (Fales and Fritz, 2007).

Potassium being a primary nutrient, plays many crucial roles in the plant including activating enzyme, opening and closing of stomata, efficient transport of water and nutrient through the xylem and finally in protein synthesis in the plant (Barker and Culman, 2020). In recent times; the intensive agricultural practices along with diversified use of cow dung has caused a broken potassium cycle which leads to higher potassium mining than potassium replenishment leading to potassium deficiency in both plant and animal (Hasan, 2002; Römheld and Kirkby, 2010). As a result, there is a dire need for formulation of efficient potassium management practice for forage crops (Pant *et al.,* 2004).

Zinc is also essential as a micronutrient (Hafeez *et al.,* 2013). Zinc is the only metal represented in all six enzyme classes (Broadley *et al.,* 2007). It also acts in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, and pollen formation (Brown *et al.,* 1993; Cakmak, 2002; Mousavi, 2011). Zn is required for the synthesis of tryptophan which is a precursor of growth-promoting hormone, i.e. auxin (Shukla and Prasad, 1974). Not only the growth; zinc also plays an important role in fodder quality too (Mahdi *et al.,* 2012; Mohan *et al.,* 2015). Despite all these critical roles played by zinc in the plant; more than 50% of the Indian soil, especially in the Indo-Gangetic plain, is deficient in zinc which often leads to widespread zinc deficiency especially in zinc sensitive crop like maize (Sharma, 2006; Alloway, 2008; Sidhu and Sharma, 2010). Due to these factors, regular supply of zinc is needed in maize raising both as food and forage crops.

Another method of enhancing the growth and development of plant without hampering the soil health is the incorporation of plant growth-promoting rhizobacteria (PGPR).The PGPR inoculants which are currently commercialized seem to promote growth either through suppression of plant disease (Bioprotectants), improved nutrient acquisition (Biofertilizers), or phytohormone production (Biostimulants) (Prasad *et al.,* 2015; Vejan *et al.,* 2016). Considering all these factors, this experiment was chalked out to evaluate the efficacy of integrated nutrient management treatments consisting of potassium, zinc and PGPR on different quality aspects of maize.

MATERIALS AND METHODS

The experiment was carried out at the Agronomy research block, ICAR-National Dairy Research Institute, Karnal (Haryana) located at 29Ú45’ N latitude, 76Ú58’E longitude and an altitude of 245 m above mean sea level. The research station falls under sub-tropical climatic zone characterized by sweltering temperatures during summer and severe cold during winter. This zone receives rainfall from both southwest and northeast monsoons. During the field experiment; highest rainfall of 8.7 mm was recorded in the 33rd standard meteorological week (13th to 19th August), and there was no rain during 32nd, 34th, 37th and 41st standard meteorological week. The highest and lowest relative humidity of 97.9% and 63.7% was recorded during 40th standard meteorological week (1st to 7th October), the maximum temperature of 34.5! was recorded during the 37th standard meteorological week (10th to 16th September), and the minimum temperature of 20.3! was recorded in 41st standard meteorological week (7th to 14th October). The highest evaporation value of 4.1 mm recorded during the 38th standard meteorological week (17th-23rd September) during the crop period. The soil characteristics of the experimental site are sandy clay loam in texture, near neutral in reaction, medium in organic carbon, low in available nitrogen and zinc, and medium in available phosphorus and potassium.

The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatments which were replicated thrice. The treatments were, T_1– control (No K), T_2 -100% RDK (recommended dose of potassium), T_3 -100% RDK+0.5% Zn as foliar spray, T_4 - 75% RDK+PGPR (plant growth promoting Rhizobacteria), T_5 - 100% RDK+PGPR, T_6 - 75% RDK+PGPR+0.5 % Zn as foliar spray, T_7 - 100% RDK+PGPR +0.5 % Zn as foliar spray, T_8 - 75% RDK+PGPR+FYM (5 t ha^{-1}) +0.5 % Zn foliar spray, T_9 - 100 % RDK+PGPR+ FYM (Farmyard Manure)

(5 t ha^{-1}) + 0.5% Zn foliar spray at 35 DAS and 50 DAS. The recommended dose of potassium for maize is 40 kg K_2O ha^{-1} in Haryana.

Sowing was performed on the sufficiently levelled plots with a mild gradient in one side to facilitate proper irrigation and drainage. The maize variety of J-1006 with a seed rate of 40 kg ha^{1} and spacing of 30 x 10 cm was used in this experiment. All the plots were supplied with 100 kg of N ha^{-1} and 60 kg of P_2O_5 ha^{-1} in which full dose of P_2O_5 and half dose of N was applied as basal dose while the remaining half of the N was supplied on the knee-high stage by broadcasting. In T_8 and T_9 plots; well, rotten FYM was applied during final field preparation. The potassium (K_2O) was applied as basal application and as per the treatments. The maize seeds were treated with PGPR inoculums by diluting 50 ml of PGPR solution in 1 litre of water in which seed was soaked for overnight, air-dried in the shade before sowing in the field.

To eliminate border effect; two rows on both sides and 0.5 m length at each end of the plot was not included in the experiment, and the net plot area was harvested separately from each plot. To check out the quality of the fodder crop, representative samples were oven-dried sample at 60°C to constant weight to determine dry matter (DM) content, was ground using a Wiley mill to pass through a 1 mm sieve and were stored into an airtight polythene bags till further analysis. Proximate principles namely crude protein (CP), crude fibre (CF), ether extract (EE) and ash was determined according to AOAC (1990). Neutral detergent fibre, acid detergent fibre and acid detergent lignin were measured following methods of Van Soest *et al.,* 1991. Data obtained were statistical analysed using SPSS 19.0 Version for its test of significance.

RESULTS AND DISCUSSIONS

The perusal of experimental data revealed that application of different nutrient sources such as potassium, zinc, FYM and PGPR had significantly ($p=0.05$) improved the fodder yield and quality of maize over the control. Significantly higher ($p=0.05$) green fodder as well as dry fodder yield was obtained with application of 100 % RDK +PGPR+FYM+0.5% Zn spray and found to be at par with application of 75 % RDK +PGPR+ FYM + 0.5% Zn spray and 100 % RDK+PGPR+ 0.5% Zn spray.

An increase in green fodder yield maybe due to stimulating effect of potassium and zinc on the

Table 1. Effect of different nutrient management comprising potassium, zinc, PGPR and FYM on dry matter (%), organic matter (%), and ash content (%) of fodder Maize

Treatments	Green fodder yield (t ha^{-1})	Dry matter Yield (t ha^{-1})	OM (%)	DM (%)	Ash (%)
T_1	30.5	5.9	91.7	16.8	8.3
T_2	44.7	8.2	90.4	19.5	9.6
T_3	43.1	8.3	90.4	19.1	9.6
T_4	37.5	6.8	90.8	18.8	9.1
T_5	43.4	8.3	90.4	19.2	9.6
T_6	37.3	6.9	90.9	18.9	9.1
T_7	50.4	9.5	90.0	20.4	10.0
T_8	49.7	9.3	90.6	20.7	10.0
T_9	51.4	9.7	89.9	21.2	10.1
SEm±	2.1	0.4	0.49	0.7	0.2
CD (P=0.05)	4.4	0.7	1.02	1.5	0.3

Note: T_1 - No K, T_2 -100% RDK, T_3 -100% RDK+0.5% Zn as foliar spray, T_4 - 75% RDK+PGPR, T_5 - 100% RDK+PGPR, T_6 - 75% RDK+PGPR+0.5 % Zn as foliar spray, T_7 - 100% RDK+PGPR+0.5 % Zn as foliar spray, T_8 - 75% RDK+PGPR+ FYM+ 0.5 % Zn foliar spray, T_9 - 100 % RDK+PGPR+FYM+ 0.5% Zn foliar spray for two times. OM, organic matter; DM, dry matter biological activity of the plant. The potassium and zinc promote photosynthetic pigment and activates various types of enzyme which are involved in a varied type of metabolic activity. Foliar spray of zinc enhances the function of ps-2nd which increases the photosynthesis rate and promotes the formation of tryptophan which is a precursor of auxin hormone that finally leads to the rapid growth rate. Potassium also helps in easy translocation of assimilates resulting in improvement of net assimilation rate (NAR) which finally trigger higher fodder yield (Kumar *et al.,* 2015, 2018).

Significantly (P=0.05) higher organic matter content (91.7%) was recorded in the control treatment followed by treatments where 75% RDK+PGPR+0.5% Zn spray (T_6) and 75% RDK+PGPR (T_4) were applied. The lowest organic matter (89.9%) content was recorded on the treatment where 100 % RDK+PGPR+ FYM+0.5% Zn foliar spray was applied (Table 1). It was observed that organic matter content decreased with increasing the nutrient application under different treatments. This might be due to the inverse relation of OM with total ash content in the fodder sample. On the other hand, significantly higher DM (%) was attained from treatment of 100% RDK+PGPR+FYM (5 t ha^{-1}) + 0.5% Zn spray which was at par with treatment having application of 75% RDK+PGPR+FYM+0.5% Zn spray and another treatment with 100% RDK+PGPR+ 0.5% Zn spray over the control (Table 1). Similar result with the application of potassium, zinc, PGPR and FYM were earlier reported by other research workers (Ahmad *et al.,* 2009; Singh *et al.,* 2016; Chand *et al.,* 2017).

As mentioned earlier, the data on total ash content (%) of fodder maize (Table 1) indicates that different nutrient management regime has significantly (P=0.05) improved the ash content (%) over the control. Higher ash content (%) was obtained with application of 100% RDK+PGPR+FYM (5 t ha^{-1}) +0.5% Zn spray and found at par with application of 75% RDK+ GPR+ FYM (5 t ha^{-1})+ 0.5% Zn spray and 100% RDK+PGPR+0.5% Zn spray, respectively. This might be due to the favourable effect of balanced nutrition on growth and development of plants which further increases the nutrient demand leading to higher assimilation of nutrients within the plant system. Again; synergistic effect of zinc with nitrogen, potassium, and some other micronutrient also contribute to the ash content of the fodder crop (Balabanli *et al.,* 2010; Jamil *et al.,* 2015).

Significantly (P=0.05) higher CP (crude protein)

Table 2. Effect of different nutrient management comprising potassium, zinc, PGPR and FYM on crude protein content (%), crude protein yield (t ha^{-1}) and ether extract content (%) of fodder maize

Treatments	CP (%)	CP yield(t ha^{-1})	EE (%)
T_1	7.29	0.43	1.64
T_2	8.71	0.72	2.03
T_3	8.63	0.71	2.09
T_4	8.25	0.56	1.90
T_5	8.67	0.72	2.02
T_6	8.13	0.56	1.89
T_7	8.63	0.82	2.27
T_8	8.69	0.81	2.23
T_9	8.77	0.85	2.29
SEm±	0.14	0.01	0.07
CD (P=0.05)	0.29	0.1	0.14

T_1 - No K, T_2 -100% RDK, T_3 -100% RDK+0.5% Zn as foliar spray, T_4 - 75% RDK+PGPR, T_5 - 100% RDK+PGPR, T_6 - 75% RDK+PGPR+0.5 % Zn as foliar spray, T_7 - 100% RDK+PGPR+0.5 % Zn as foliar spray, T_8 - 75% RDK+PGPR+ FYM+ 0.5 % Zn foliar spray, T_9 - 100 % RDK+PGPR+FYM+ 0.5% Zn foliar spray for two times; CP, crude protein; EE, ether extract

Table 3. Effect of different nutrient management comprising potassium, zinc, PGPR and FYM on NDF (%), ADF (%) and ADL (%) content of fodder Maize

Treatments	NDF (%)	ADF (%)	ADL (%)
T_1	69.0	39.5	5.45
T_2	64.8	35.6	4.88
T_3	64.0	35.7	4.83
T_4	67.5	37.5	5.15
T_5	64.4	35.3	4.90
T_6	66.2	37.6	5.14
T_7	62.3	33.3	4.59
T_8	62.4	33.2	4.60
T_9	62.2	33.1	4.53
SEm±	0.6	0.6	0.08
CD (P=0.05)	1.3	1.2	0.16

T_1 - No K, T_2 -100% RDK, T_3 -100% RDK+0.5% Zn as foliar spray, T_4 - 75% RDK+PGPR, T_5 - 100% RDK+PGPR, T_6 - 75% RDK+PGPR+0.5 % Zn as foliar spray, T_7 - 100% RDK+PGPR+0.5 % Zn as foliar spray, T_8 - 75% RDK+PGPR+ FYM+ 0.5 % Zn foliar spray, T_9 - 100 %

content of maize (Table 2) was recorded on 100 % RDK+PGPR+FYM+0.5% Zn foliar spray followed by application of 100% RDK and 75% RDK+PGPR+ FYM+0.5 % Zn foliar spray. Similarly; crude protein yield, which is a function of crude protein content and dry matter yield, was also improved owing to the different nutrient application than the control. Highest crude protein yield was recorded on the treatment of 100 % RDK+ PGPR+FYM+0.5% Zn foliar spray which is found to be statistically at par with application of 75% RDK+PGPR+FYM+ 0.5 % Zn foliar spray and application of 100% RDK+PGPR+0.5 % Zn foliar spray. Potassium plays an important role in the activation of nitrate reductase enzyme that involves in the protein synthesis process, thus increase CP yield (Hasanuzzaman *et al.,* 2018). Zn is essential for the activity of RNA polymerase, protects ribosome and is also involved in function and stability of genetic material that plays a direct role in amino acid synthesis resulting in improved protein content (Moinuddin and Imas, 2010, Panda *et al.,*2020).

The experimental data revealed that the EE was significantly (*p=0.05*) higher in 100 % RDK+PGPR+ FYM+0.5% Zn foliar sprayapplication and found to bestatistically at par with application of 100% RDK+PGPR+ .5 % Zn as foliar spray (Table 2). These results are in conformity with (Kumar *et al.,* 2019).

Data pertaining to different fibre fractions (NDF, ADF and ADL) of fodder maize as influenced by different nutrient management are presented in table 3. In general, lower values of fibre fractions are considered to be better. The data obtained from the experiment recorded significantly (*p=0.05*) lower value on application of 100% RDK+PGPR+FYM+0.5% Zn spray and found at par with application of 75% RDK+ PGPR+FYM+0.5% Zn spray and 100% RDK+PGPR +0.5% Zn spray over the control. The reduction of fibre fraction indicates an improvement in fodder quality which could be due to the combined application of potassium and zinc in the presence of FYM which reduces the soluble carbohydrate content in plant tissue and promotes protein synthesis (Chand *et al.,* 2017).

CONCLUSION

The conclusion from this experiment can be drawn that integrated nutrient management with a recommended dose of potassium, foliar spray of zinc, 5-ton FYM helps to attain the higher quantity and quality of fodder maize production.

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