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NUTRIENT UPTAKE AND USE EFFICIENCY OF MAIZE (*ZEA MAYS* L.) AS INFLUENCED BY MICROBIAL SEED INOCULATION, NPK FERTILIZATION AND PANCHAGAVYA FOLIAR APPLICATION

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ABSTRACT

The nutrient use efficiency of maize (*Zea mays* L.) due to NPK fertilization alone is low, while, an integrated use of nutrients enhances the uptake and efficiencies of applied nutrients. A field study was carried out to test the effect of fertilizer NPK, microbial seed treatment and panchagavya on grain yield, nutrient uptake and use efficiencies of relay cropped maize during the summer season of 2018 in Annamalai University Experimental Farm, Annamalainagar, Tamil Nadu. Thirteen treatments comprised of 100, 75 and 50% of RDF in combination with and without seed treatment of microbial consortia and 3% panchagavya foliar spray at knee high and pre-tasseling stages. The maximum grain yield, NPK uptake, physiological efficiency, internal efficiency and unit area efficiency were registered with integrated application of 100% RDF (250:75:75 kg N, P_2O_5 and K_2O/ha) along with seed treatment with microbial consortium and foliar application of panchagavya at knee high and pre-tasseling stages. However, grain yield and NPK uptake were statistically on par with integrated application of 75% RDF (188: 56: 56 N, P_2O_5 and K_2O kg/ha), seed treatment with microbial consortium (20 ml/kg) and 3% panchagavya foliar application at knee high and pre-tasseling stages. The agronomic efficiency, apparent nutrient recovery, value cost ratio was high in integrated application of 75% RDF, seed treatment with microbial consortium and 3% panchagavya foliar application at knee high and pre-tasseling stages and was considered as an effective agro-technology.
Keywords : Coastal agroecosystem, biofertilizers, foliar fertilization, nutrient uptake, relay cropping, rice based cropping system

Introduction

Rice (*Oryza sativa* L.) and maize (*Zey mays* L.) crops are grown either as a monocropping or in sequential cropping in tropical and sub-tropical/irrigated regions of India. In the irrigated areas, rice-maize relay/ fallow cropping under zero till condition is emerged as one of the most important cropping system. Rice-maize cropping systems are followed mostly in the northeast (Bihar and West Bengal) and south (Andhra Pradesh, Karnataka and Tamil Nadu) regions of India with an area of more than 0.5 mha (Ahirwar and Khan, 2019). This system meets the twin requirements such as food stuff of a fast growing human population and feed demand of livestock.

Monsoon failures and decline in availability of irrigation water replaced the rice-rice cropping system in to rice–maize cropping system. Rice (*Oryza sativa* L.)-maize (*Zea mays* L.) cropping systems are prevalent in mostly all agro-climatic regions of southern India (Mahto *et al*. 2018; Rex Immanuel *et al*. 2019a). Yield potential of rice and maize, as estimated by Oryza, 2000 and hybrid maize models, reaches up to 15 and 22 t ha^{-1}, respectively (Ahirwar and Khan, 2019). In recent years, popularity of maize as relay crop is increased (Leela Rani and Yakadri, 2017; Rex Immanuel *et al*., 2020).

Intensive cropping systems with high yielding maize hybrids will lead to the very fast depletion of plant nutrients from rhizosphere because of the greater nutrient uptake and removal by maize than other cereals. Hence, monitoring the nutrient uptake and its use efficiency by maize crop in rice-maize cropping system is paramount important. Mineral fertilizers are used to provide soil nutrients in order to maintain optimum soil fertility conditions, growth of the plants and quality yield (Sudhagar Rao *et al*., 2017).

In rice growing coastal regions of Tamilnadu, there is an acute shortage of irrigation water for raising nursery and delayed transplanting, which caused reduced crop yield as well as failure of second crop. As a result, wet spot seeded rice in puddled soils followed by relay cropped maize can be a substitute for sustaining the small and marginal farmer's livelihood (Rex Immanuel *et al*., 2018).

Maize crop has better yield response to inorganic fertilizers however heavy doses of fertilizer application lead to nutrient losses through leaching, volatilization and finally involved in to the deterioration of associated ecosystems (Kalhapure *et al*., 2013). The degraded nature of the soils especially in coastal agroecosystems further affects the crop production and hence these lands are diverted to other land uses (Rex Immanuel and Ganapathy, 2019b; Rex Immanuel and Ganapathy, 2019c).

Inadequate N nutrition could severe effect on maize yield as the plant would remain stunted and rapidly turn yellow if adequate N is not available for the chlorophyll formation and protein synthesis (Asibi *et al.*, 2019). Phosphorus is an essential component of DNA, RNA and other compounds essential for plant structure, seed yield and genetic transfer. Phosphorus is also a crucial component of ATP and involved from the early seedling growth to the formation of grain and maturity (Belay *et al.*, 2002). Potassium has significant role in plant water relations where it regulates ionic balances within cells and also plays a significant role in the activation of more than 60 enzymes which catalyze various metabolic process and uptake and translocation of nutrients (Evans and Wildes, 1971). Potassium deficiency strongly affects nitrogen metabolism and photosynthesis in maize (Qu, 2011). Hence, application of NPK is essential for enhancing the productivity.

However, more than 50 to 75er cent of applied nutrients are not taken up by crops. The recovery of applied N by maize rarely exceeds 50 per cent (Conant *et al*., 2013). Group of biofertilizers inoculation can increase the yield of grain crops and have involved in fixation, mobilization and mineralization of nutrients. It also helps to increase the uptake and efficiency of applied nutrients. The inoculation of plants with a bacterial mixture (consortium) apparently provides greater benefits to plants than inoculation with a single bacterial strain (Molina-Romero *et al*., 2017). The application of recommended dose of fertilizers along with foliar spray of panchagavya increased the yield of hybrid maize with due care on soil fertility (Sudhagar Rao *et al*., 2019).

Materials and Methods

A field experiment was conducted during Zaid season (March – June) of 2018 at the Annamalai University Experimental Farm, Department of Agronomy, Annamalainagar, Tamil Nadu (11°24' North latitude, 79°44' East longitude and +5.79 msl) to study the productivity, nutrient uptake and nutrient use efficiency of hybrid maize under various nutrient management practices.

The weather of study area is moderately warm with hot summer months. The mean annual rainfall was 1450 mm and about 80% is received during North East monsoon. The study period experiences the maximum temperature between 30.9° and 38.0°C while the minimum temperature fluxgates from 17.8° to 27.4°C with the average relative humidity of 83.67%. The crop received a total rain fall of 68 mm in 4 rainy days. The soil is clay loam in texture with low in available N (169 kg/ha), medium in available P (9.91 kg/ha) and available K (279 kg/ha).

The hybrid maize SMH 7930 was used for the study. The experiment was laid out in Randomized Block Design (RBD) replicated thrice. The treatments consisted of T_1-100% Recommended dose of fertilizer (250:75:75 kg N, P_2O_5 and K_2O/ha) - RDF), T_2-75% RDF, T_3-50%RDF, T_4-T_1 + seed treatment with microbial consortium (STMC), T_5 - T_2 + STMC, T_6 - T_3 + STMC, T_7 - T_1 + foliar application of panchagavya @ 3% at knee-high and pre tasseling stages (KPTS), T_8 - T_2 + foliar application of panchagavya @ 3% at KPTS, T_9 - T_3 + foliar application of panchagavya @ 3% at KPTS, T_{10} - T_4 + foliar application of panchagavya @ 3% at KPTS, T_{11} - T_5 + foliar application of panchagavya @ 3% at KPTS, T_{12}-T_6 + foliar application of panchagavya @ 3% at KPTS and T_{13}–Control (without manuring).

Panchagavya was prepared by the method suggested by Raghavendra *et al.* (2014). The seeds were treated with microbial consortium at the rate of 20 mL/kg and dried under shade for 30 minutes and used for sowing. The microbial consortium contains most effective N fixing, P and Zn solubilizing, K mobilizing and plant growth promoting bacterial strains (*Azospirillum lifoperum, Bacillus megaterium* and *Pseudomonas fluorescens*) in a single liquid carrier.

Relay cropping system was followed for maize cultivation. In which seeds were sown before the harvesting of rice with the waxy condition of the field. The seeds were dibbled at the rate of one seed per hole to a depth of three cm with a spacing of 60x20 cm. Gap filling was done on 10^{th} days after sowing (DAS). First weeding and hoeing was given on 20 DAS. Second hand weeding and earthing up was done on 45 DAS. Need based plant protection measures were also followed. As per the treatment 50% of N and entire dose of P_2O_5 and K_2O were applied at 20 DAS and remaining N was applied as two equal splits at 30 and 45 DAS. Apart from rainfall three irrigations were given knee high, tasseling and silking stage of the crop.

The crop samples collected at the time of harvesting from outside the net plot was used for analysis of N (Yoshida *et al*., 1976), P and K uptake (Jackson, 1973) by crops. The agronomic efficiency is the response in yield per unit input as indicated by the following formula (Yoshida, 1981) and expressed in kg kg^{-1}.

$$AE = \frac{G_F - G_U}{N_a}$$

Where, G_f - Grain yield in fertilized plot (kg ha^{-1}), G_u - Grain yield in unfertilized plot (kg ha^{-1}) and Na - Quantity of fertilizer Nutrients applied (kg ha^{-1}) like N, P and K.

Apparent nutrient recovery efficiency is defined as the quantity of nutrients absorbed per unit of nutrients applied. It was computed as per the formula suggested by Pillai and Vamadevan (1978) and expressed in percentage.

$$ANR\ (\%) = \frac{Y_t - Y_o}{N_t}\ x\ 100$$

Where, Y_t = uptake of Nutrient in particular treatment (kg ha^{-1}), Y_o = uptake of Nutrient in unfertilized plot (kg ha^{-1}) and N_t = Quantity of Nutrient applied for the treatment (kg ha^{-1}) like N, P and K.

The physiological efficiency is the seed yield obtained per unit of nutrients absorbed. Calculated by using the following formula and the values are expressed in (kg ha^{-1}). It was computed as follows (Yoshida, 1981).

$$PE = \frac{\text{Seed yield in fertilized plot} - \text{Seed yield in un fertlized plot}}{\text{Nutrient uptake in fertilized plot} - \text{Nutrient uptake in unfertilized plot}}$$

Internal efficiency indicates per unit seed yield per unit nutrient uptake. It was worked out using the formula as given below:

$$IE = \frac{Seed\ yield\ (Kg\ ha^{-1})}{Total\ nutrient\ uptake\ (Kg\ ha^{-1})}$$

The unit area efficiency (UAE) for seed yield and total dry matter production were calculated by using the following formula and the values are expressed in g m^{-2} day^{-1}.

$$UAE\ (Seed\ yield) = \frac{Seed\ yield}{Land\ area}\ x\ \frac{1}{Duration\ of\ crop}$$

The value cost ratio (VCR) or economic efficiency helps to predict farm income and maximized from proper use of nutrient inputs, and also able to know the status of applied technologies. It is calculated by using the formula.

$$VCR = \frac{Increase\ in\ grain\ yield\ (kg\ ha^{-1})\ x\ Price\ of\ 1\ kg\ grain}{Nutrient\ added\ x\ Price\ of\ fertilizer}$$

The data on the seed yield, nutrient uptake and unit area efficiency were analyzed statistically (Gomez and Gomez, 1984). Wherever the results were found significant ('F' test), the critical differences (CD) were arrived at five per cent probability level.

Results and Discussion

Seed yield

The seed yield was varied significantly due to integrated nutrient management practices. Among them, integrated application of 100% RDF (250:75:75 kg N, P_2O_5 and K_2O/ha) along with seed treatment with microbial consortium (STMC) and foliar application of panchagavya @ 3% at knee-high and pre tasseling stages (KPTS) (T_{10}) was found to be significantly efficient by increasing the seed yield (27.33%) over 100% RDF alone; however it was statistically on par with 75% RDF, STMC and foliar application of panchagavya @ 3 % at KPTS (T_{11}) (24.51 %).

Seed inoculation with microbial consortium fixs significant quantity of atmospheric nitrogen in the soil and converts insoluble form of soil nutrients into available forms by secreting organic acids resulting in effective utilization of both applied and soil nutrients by maize which in turn resulted with better protein synthesis, numerous metabolic process, cell division, root development and dry matter assimilation leading to an efficient absorption and translocation of water and nutrients, interception of solar radiation and assimilation of carbon dioxide. Moreover, the dominant role played by foliar application of panchagavya in ensuring prompt delivery of essential nutrients, enzymes, hormones to the site of photosynthesis and assimilating capacity of crop by being a component in various enzymatic and other biochemical reactions resulted better translocation of assimilates from source to sink that enabling proper production of healthier cobs and quality seeds, resulting in higher grain yield. Gains on maize grains yield with microbial inoculation, inorganic nutrients and foliar panchagavya application are also reported by Lana *et al.* (2012); Tahir and Sarwar (2013) and Oliveira *et al.* (2018).

Nutrient uptake

The highest N, phosphorus and potassium uptake of 223.22 kg ha^{-1}, 41.90 kg ha^{-1} and 177.3 kg ha^{-1}, respectively were recorded under the integrated application of 100 per cent RDF along with STMC and foliar application of panchagavya @ 3 per cent at KPTS (T_{10}). It was statistically on par with integrated application of 75 per cent RDF, STMC and foliar application of panchagavya @ 3 per cent at KPTS (T_{11}) by registering N uptake of 222.27 kg ha^{-1}, 40.76 kg ha^{-1} and 176.02 kg ha^{-1}, respectively. The increased uptake of N, P and K with integrated application of inorganic, organic and biological source of plant nutrients favoured the enormous availability of nutrients thus resulted in initial soil build up favouring vigorous growth and higher photosynthetic rate which led to better uptake of nutrient by maize under Utera cropping. Further, the application of microbial consortium reduces N losses and conserves soil N by N fixation, thus maintaining a continuous availability of N in the entire life cycle of maize crop which would resulted in the increased uptake of nitrogen. Further it also enhanced the greater availability of P and enhanced the cambial activity of root hairs, involved in root cell development and augments root proliferation and root biomass which in turn helps to allowing the plants to absorb required quantity of essential nutrients such as N, P and K from sub soil layers also. These results are in conformity with findings of Kalhapure *et al.* (2013) and Singh *et al.* (2017).

Efficiencies

The higher agronomic efficiency of nitrogen, phosphorous and potassium resulted in integrated application of 75 per cent RDF, STMC and foliar application of panchagavya @ 3 per cent at KPTS (T_{11}) by registering the value of 18.36, 61.19 and 61.19, respectively. The maximum apparent nutrient recovery of nitrogen, phosphorous and potassium was recorded in integrated application of 75 per cent RDF, STMC and foliar application of panchagavya @ 3 per cent at KPTS (T_{11}) by registering the value of 72.08, 44.50 and 188.65, respectively.

The higher physiological efficiency of nitrogen, phosphorous and potassium resulted in integrated application of 100 per cent RDF along with STMC and foliar application of panchagavya @ 3 per cent at KPTS (T_{10}) by registering the value of 26.25, 141.91 and 33.06, respectively. The higher internal efficiency of nitrogen, phosphorous and potassium recorded in integrated application of 100 per cent RDF along with STMC and foliar application of panchagavya @ 3 per cent at KPTS (T_{10}) by registering the value of 26.27, 143.40 and 33.06, respectively.

Among the various treatments, the integrated application of 100 per cent RDF along with seed treatment with microbial consortium and foliar application of panchagavya @ 3 per cent at knee high and pre tasseling stages (T_{10}) recorded the more unit area efficiency of 5.98 g m^{-2} day^{-1}. This treatment was statistically on par with integrated application of 75 per cent RDF, seed treatment with microbial consortium and foliar application of panchagavya @ 3 per cent at knee high and pre tasseling stages (T_{11}) by registering a value of 5.85 g m^{-2} day^{-1}.

Various efficiencies were greatly influenced by the balanced use of inorganic sources of plant nutrients, microbial inoculants and panchagavya. It might be owing to beneficial effect of combined application of inorganic fertilizer along with microbial inoculants and liquid organic manure on crop growth, which influenced the growth and yield attributing characters positively. Microbial inoculants possessing both N fixing and P solubilizing traits have the highest potential to improve the crop yield and nutrient uptake resulted in improved assessing efficiencies greatly. Similar results were obtained by Duan *et al.* (2014), Kakraliya *et al.* (2017), Schutz *et al.* (2018) and Bradacova *et al.* (2019).

Value cost ratio

The integrated application of 75 per cent RDF, seed treatment with microbial consortium and foliar application of panchagavya @ 3 per cent at knee high and pre tasseling stages (T_{11}) recorded the highest value cost ratio of 8.52. This might be due to the introducing of inorganic, organic and biological sources of plant nutrients in reducing the purchase cost of high analyzed fertilizer inputs.

Conclusion

The microbial consortia seed inoculation, NPK fertilization and panchagavya foliar application on relay cropped maize significantly influenced the nutrient uptake and use efficiency. The maximum grain yield, NPK uptake agronomic efficiency, apparent nutrient recovery, value cost ratio were high in integrated application of 75% RDF (188: 56: 56 N, P_2O_5 and K_2O kg/ha), seed treatment with microbial consortium (20 mL/kg)and 3% panchagavya foliar application at knee high and pre-tasseling stages and was considered as an effective nutrient management technology for relay cropped maize.

Table 1 : Effect of nutrient management practices on nutrient uptake and efficiencies of maize

Treatments	Seed yield (t/ha)	Nutrient uptake (kg ha^{-1})			Agronomic efficiency			Apparent nutrient recovery		
		Nitrogen	Phosphorus	Potassium	N	P	K	N	P	K
T_1	4.61	178.42	32.78	141.73	9.26	30.88	30.88	36.52	22.73	96.52
T_2	3.96	153.42	28.46	123.01	8.87	29.56	29.56	35.36	23.63	95.41
T_3	2.80	110.29	21.19	100.97	4.07	13.57	13.57	18.53	14.56	84.34
T_4	5.32	202.97	38.12	161.87	12.14	40.47	40.47	46.34	29.85	123.37
T_5	4.77	183.21	33.63	144.82	13.22	44.05	44.05	51.25	31.82	134.19
T_6	3.93	151.77	27.62	121.67	13.08	43.60	43.60	51.72	31.71	95.41
T_7	5.17	198.70	36.45	159.16	11.52	38.39	38.39	44.63	27.63	119.76
T_8	4.02	155.70	29.07	125.99	9.20	30.67	30.67	36.58	23.72	100.71
T_9	3.59	139.62	25.09	109.09	10.38	34.59	34.59	42.00	24.96	139.55
T_{10}	5.87	223.22	41.90	177.30	14.29	47.63	47.63	54.44	33.56	144.07
T_{11}	5.74	222.27	40.76	176.02	18.36	61.19	61.19	72.08	44.50	188.65
T_{12}	4.48	176.1	32.17	139.98	17.48	58.27	58.27	71.18	43.84	188.37
T_{13}	2.29	87.12	15.73	69.34	-	-	-	-	-	-
SEm±	0.11	2.47	0.85	1.83	-	-	-	-	-	-
CD (P=0.05)	0.33	7.20	2.48	5.36	-	-	-	-	-	-

Table 2 : Effect of nutrient management practices on efficiencies and value cost ratio of maize

Treatments	Physiological efficiency			Internal efficiency			Unit area efficiency	Value cost ratio
	N	P	K	N	P	K		
T_1	25.37	135.84	31.99	25.83	140.60	32.52	4.70	4.47
T_2	25.08	130.64	30.99	25.79	139.00	32.16	4.04	4.47
T_3	21.97	93.22	16.09	25.41	132.23	27.75	2.86	2.76
T_4	26.20	135.55	32.80	26.25	139.77	32.92	5.44	5.70
T_5	25.79	138.44	32.83	26.04	141.89	32.94	4.87	6.33
T_6	25.29	137.51	30.93	25.88	142.22	32.28	4.01	6.61
T_7	25.80	138.95	32.05	26.03	141.89	32.50	5.28	5.43
T_8	25.15	129.31	30.45	25.81	138.22	31.89	4.10	4.61
T_9	24.70	138.57	32.63	25.71	140.08	32.91	3.66	5.46
T_{10}	26.25	141.91	33.06	26.27	143.40	33.06	5.98	6.61
T_{11}	25.47	137.51	32.26	25.80	140.70	32.58	5.85	8.52
T_{12}	24.56	132.91	30.93	25.43	139.20	31.99	4.57	8.49
T_{13}	-	-	-	-	-	-	2.34	-
SEm±	-	-	-	-	-	-	0.10	
CD (P=0.05)	-	-	-	-	-	-	0.30	

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