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Uptake of Macro Nutrients by Java Citronella as Influenced by Nutrient Management Under Inceptisols

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Abstract: *Field study was conducted during kharif 2009-10 and 2010-11 at Nagarjun Medicinal and Aromatic Plants Garden, Dr. P.D.K.V., Akola (M.S.). The experimental soil was calcareous in nature and moderately alkaline in reaction. The fertility status of the soil was moderate in organic carbon, low in available nitrogen and available phosphorus and very high in available potassium while the soil micronutrient contents (Zn, Fe, Mn, Cu) were above the critical level. Experiment comprised of thirteen treatments replicated thrice in randomized block design, involving control (no fertilizer/manure), 5 t FYM ha^{-1}, 10 t FYM ha^{-1}, 80:20:40 kg NPK ha^{-1}, 100:30:60 kg NPK ha^{-1}, 140:40:80 kg NPK ha^{-1}, 5 t FYM + 80:20:40 kg NPK ha^{-1}, 5 t FYM + 100:30:60 kg NPK ha^{-1}, 5 t FYM + 140:40:80 kg NPK ha^{-1}, 10 t FYM + 80:20:40 kg NPK ha^{-1}, 10 t FYM + 100:30:60 kg NPK ha^{-1}, 10 t FYM + 140:40:80 kg NPK ha^{-1} and 100 kg N through FYM (based on FYM analysis). Results indicated that, the highest N, P, K and S uptake was noticed with combined application of FYM + NPK (10 t FYM + 140:40:80 kg NPK ha^{-1}).*

Hence, it can be concluded that the conjunctive use of FYM along with chemical fertilizer (10 t FYM + 140:40:80 kg NPK ha^{-1}) was found beneficial way of nutrient management for improving uptake of macro nutrients (N, P, K and S) by Java citronella.

Keywords: *Java citronella, Nutrient management, Inceptisol and Uptake of Macro Nutrients.*

INTRODUCTION

Cymbopogon winterianus commonly known as Java citronella belongs to Graminae family and is originally from Sri Lanka and it is a tall perennial tufted aromatic grass with superficial fibrous roots. It is basically, a tropical plant mainly cultivated in Indonesia, Sri Lanka, China and India. In India, major producing area is the tea gardens in Assam and to a limited extent in states like U.P., Maharashtra, Karnataka, Gujarat, Manipur, Meghalaya, Tamil Nadu, Nagaland, Uttaranchal, A.P. and Tripura where it is commercially cultivated and distilled for its oil (Shiva *et al.*, 2002). Java citronella has a world production of 1600 tons per year and out of which 500 tones is produced in India on 9000 ha area. India stands 3rd position in essential oil production in the world. There is a large scope to cultivate this Aromatic crop. The market demand up to the year 2025 in the India is estimated to 3200 ha and 66000 ha in World (Anonymous, 2004).

It is a long duration crop and takes away sizable quantities of nutrients from the soil producing a large biomass of herbage in a cycle of 4 to 5 years growth under cultivation. The crop is

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estimated to remove 181.00 kg ha^{-1} N (0.50-1.80% content), 32.80 kg ha^{-1} P (0.20-0.30% content) and 255.30 kg ha^{-1} K (1.00-1.80% content) from the soil respectively in a harvest of 53.9 t ha^{-1} of dry matter in two years (Prakasa Rao and Puttanna, 2006). It accumulates the biomass and nutrients very rapidly only after five months of planting and the biomass production and nutrient uptake was found to be highest after ten months of plant growth. The concentrations of N, P and K did not fluctuate much throughout year (Prakasa Rao and Ganesha Rao, 1986).

Since, these grasses are perennial in nature the nutrient depletion is a cause of concern for sustaining the yields over a long period of time. To understand the exact pattern of nutrient removal by Java citronella the present investigation was carried out.

MATERIAL AND METHODS

Study Sites

The experiment was conducted during *Kharif* seasons of 2009-10 and 2010-11 at Nagarjun Medicinal Plants Garden, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (latitude of 22° 41' N and longitude of 77°02' E with an altitude 307.41 meters). The climate of experimental site is semi-arid and subtropical with extreme conditions having hot and dry summer and cold winter, where maximum temperature goes up to 42.6°C during summer and minimum as low as 10.3°C during winter. The annual average rainfall of area is 764.7 mm. The soil of the experimental field is medium black, Smectitic, clay loam in texture and classified as *Typic Haplustept* which comes under the soil order Inceptisol. The experiment was laid out with randomized block design having three replication comprising of 13 treatments, *viz.* Control (no fertilizer/manure), 5 t FYM ha^{-1}, 10 t FYM ha^{-1}, 80:20:40 kg NPK ha^{-1}, 100:30:60 kg NPK ha^{-1}, 140:40:80 kg NPK ha^{-1}, 5 t FYM + 80:20:40 kg NPK ha^{-1}, 5 t FYM + 100:30:60 kg NPK ha^{-1}, 5 t FYM + 140:40:80 kg NPK ha^{-1}, 10 t FYM + 80:20:40 kg NPK ha^{-1}, 10 t FYM + 100:30:60 kg NPK ha^{-1}, 10 t FYM + 140:40:80 kg NPK ha^{-1} and 100 kg N through FYM (based on FYM analysis). Treatment wise FYM was added on dry weight basis before planting of Java citronella during 2009-10 contain 0.67% N, 0.22% P and 0.49% K and in the month of April 2010 contain 0.64% N, 0.20% P and 0.51% K after 3rd cutting as per treatments. Treatment wise Nitrogen, Phosphorus and Potassium doses were applied in both the years (2009-10 and 2010-11).

Nitrogen was applied through urea in three split doses as per treatment after each cutting. Full dose of Phosphorus and Potassium was applied as a basal dose at the time of planting through single super phosphate and muriate of potash as per the treatments. Java citronella 'Bio-13' was planted (rooted slips @ 16666 slips ha^{-1}) on 7th July 2009 at a spacing of 90 × 60 cm. The irrigation to the plantation was given immediate after transplanting and during the growing period, as and when required throughout the experimentation. Harvesting was done by cutting the grass close to their bases 10-12 cm above ground level. In the two years of field experimentation total six cuttings were undertaken.

Method of Plant Sample Collection

Treatment wise plant samples were selected randomly from each net plot and cut near the ground surface at each cutting. Plant samples were air dried in shade and then placed in oven at 65°C till the constant weight obtained. The oven dried weights were recorded. These plant samples were ground in electrically operated stainless steel blade grinder (Willey mill) up to maximum fineness. The ground samples stored in polythene bags with proper labeling for chemical analysis. The total nutrients content in leaves was determined and uptake was computed by multiplying the respective nutrient concentration in per cent by dry matter at each cutting.

Methods of Plant Sample Analysis

Processed plant samples were analyzed for determination of total nutrients content by adopting standard methods. Total nitrogen was determined by digesting the plant sample in microprocessor based digestion system using conc. H_2SO_4 and salt mixture (Piper, 1966) and distillation with automatic distillation system. Finely ground and well mixed plant samples of each cuttings were weighted accurately (0.2 g) transferred into micro digestion

tube and 5 ml di-acid mixture (HNO_3 and $HCLO_4$ in proportion of 9:4) was added and digested on microprocessor based digester. After completion of digestion (clear white) the extract was diluted and filtered through Whatman filter paper No. 42. These extracts were used for determination of Total P, K and S.

Total phosphorus was estimated from di-acid extract by Vanadomolybdate phosphoric acid yellow colour method (Kitson and Mellon, 1944) using UV based double beam spectrophotometer. Total potassium was estimated from di-acid extract by using flame photometer (Piper, 1966). Total sulphur was determined from di-acid extract by turbidimetric method (Chesnin and Yien, 1950) using UV based double beam spectrophotometer. Statistical analysis was carried out as per procedure described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Dry Matter Yield

The data pertaining to the total dry matter yield of Java citronella computed from three cuttings of each year is presented in table 1.

Effect of organic manure (FYM)

It is evident from the data that the alone application of FYM significantly increased the dry matter yield during both the years. Among the FYM treatments, the 10 t FYM ha^{-1} (T_3) recorded significantly maximum dry matter yield as compared to control (T_1) and 5 t FYM ha^{-1} (T_2), however it was at par with 5 t FYM ha^{-1} (T_2) during first year. Pareek *et al.* (1983) and Anonymous (1998) reported that application of FYM @ 10 t ha^{-1} increase the dry matter yield of Palmarosa than no FYM application.

Table 1
Dry matter yield of Java citronella as influenced by different treatments of nutrient management

Treatments	*Total Dry matter yield (q ha^{-1})**		
	2009-10	*2010-11*	*Pooled mean*
T_1 – Control	22.71	19.97	21.34
Organic manure doses (t ha^{-1})			
T_2 - 5 t FYM ha^{-1}	35.50	45.87	40.69
T_3 - 10 t FYM ha^{-1}	40.15	52.29	46.22
NPK fertilizer doses (kg ha^{-1})			
T_4 - 80:20:40 kg NPK ha^{-1}	63.77	68.59	66.18
T_5 - 100:30:60 kg NPK ha^{-1}	68.24	72.12	70.18
T_6 - 140:40:80 kg NPK ha^{-1}	75.00	75.15	75.08
Combined doses (O. M. + NPK fertilizer)			
T_7 - 5 t FYM + 80:20:40 kg NPK ha^{-1}	70.21	77.17	73.69
T_8 - 5 t FYM + 100:30:60 kg NPK ha^{-1}	76.14	79.82	77.98
T_9 - 5 t FYM + 140:40:80 kg NPK ha^{-1}	82.40	81.58	81.99
T_{10} -10 t FYM + 80:20:40 kg NPK ha^{-1}	77.77	86.84	82.31
T_{11} -10 t FYM + 100:30:60 kg NPK ha^{-1}	83.85	87.79	85.82
T_{12} -10 t FYM + 140:40:80 kg NPK ha^{-1}	90.50	94.83	92.66
Organic manure dose equivalent to 100 kg N ha^{-1}			
T_{13} -100 kg N through FYM (based on FYM analysis)	43.77	58.18	50.98
SE (m) ±	2.61	2.06	1.63
CD at 5 %	7.62	6.00	4.76

* Total dry matter yield of three cuttings of each year.

The application of 100 kg N through FYM on the basis of nitrogen analysis (T_{13}) recorded significantly dry matter yield as compared to control (T_1) and 5 t FYM ha^{-1} (T_2), however it was at par with alone application of 10 t FYM ha^{-1} (T_3). Increased in dry matter yield of rainfed Palmarosa with the application of FYM @ 15 t ha^{-1} to Vertisol as compared to control was also reported by Maheshwari *et al.* (1991a).

Effect of NPK fertilizer

Application of graded dose of NPK @ 140:40:80 kg ha^{-1} (T_6) recorded significantly highest dry matter yield as compared to T_1 (control) and T_4 (80:20:40 kg NPK ha^{-1}) however, it was found at par with T_5 (100:30:60 kg NPK ha^{-1}) during both the years of experimentation. The results are confirmed with the findings of several workers Yadav *et al.* (1984), Anonymous (1989[a]), Rao *et al.* (1990), Rao and Singh (1991) and Anonymous (2005[b]). Further, the data revealed that the dry matter yields recorded with NPK fertilizer doses was significantly higher than the dry matter yields obtained with alone application of FYM doses. The results are in agreement with the observations recorded by Anonymous (1987d).

Combined effect

In case of combination treatments, the 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}) recorded the significantly highest dry matter yield (90.50 q ha^{-1}) as compared to control (T_1) and all other treatments except, the 10 t FYM + 100:30:60 kg NPK ha^{-1} (T_{11}) which was found at par in the first year while, in second year the significantly highest dry matter yield (94.83 q ha^{-1}) was recorded with T_{12} (10 t FYM + 140:40:80 kg NPK ha^{-1}) as compared to control and all other combination treatments. Further, it is observed that the combined application of FYM along with NPK fertilizer was found to produce significantly higher dry matter yield as compared to alone application of either of FYM or NPK fertilizer.

From the pooled data it is revealed that the combined application of FYM and NPK doses significantly increased the dry matter yield as compared to their alone application treatments. Further, it is noticed that significantly higher dry matter yield (92.66 q ha^{-1}) was produced with the application of 10 t FYM along with 140:40:80 kg NPK ha^{-1} (T_{12}). It is observed from the data that, the dry matter yield of Java citronella was higher in second year than that of first year except in control treatment (T_1). Further, significantly highest dry matter yield was recorded in treatment receiving 10 t FYM + 140:40:80 kg NPK kg ha^{-1} (T_{12}). The significant increase in dry matter yield of Java citronella might be due to supply of balanced nutrition through the use of FYM and NPK fertilizer in integrated manner on physico-chemical properties of the soil resulted in solubilization of nutrients in the soil and thereby increased the availability to the plants, which resulted in better crop growth and ultimately resulted in increased dry matter yield. Similar result is also reported by Sharma *et al.* (1980), Maheshwari *et al.* (1993), Anonymous (2009) and Singh *et al.* (2011).

N Uptsake

The data in respect of nitrogen uptake recorded at different cuttings during 2009-10 and 2010-11 and its pooled results as influenced by different treatments of nutrient management is presented in table 2.

Effect of organic manure (FYM)

Among the alone application of FYM treatments (T_2, T_3 and T_{13}) the treatment receiving 100 kg N through FYM (T_{13}) recorded the highest N uptake (45.88 kg ha^{-1}) which was found statistically at par with treatment T_3 (10 t FYM ha^{-1}) during first year whereas, in second year the same treatment (T_{13}) recorded the significantly highest N uptake (61.71 kg ha^{-1}) as compared to 5 t FYM ha^{-1} (T_2) and 10 t FYM ha^{-1} (T_3). Increased in nitrogen uptake in these treatments might be due to added supply of nutrients, improved physical properties of soil and well developed root system resulting in to better absorption of water and nutrients.

Effect of NPK fertilizer

The application of NPK graded doses treatments (T_4, T_5 and T_6), the treatment receiving higher dose *i.e.* 140:40:80 kg NPK ha^{-1} (T_6) recorded the highest N uptake (84.43 kg ha^{-1}) than the 80:20:40 kg NPK

ha^{-1} (T_4) and 100:30:60 kg NPK ha^{-1} (T_5) during the first year, whereas, in the second year the treatment T_6 was found at par with treatment T_5. Chinnamma *et al.* (1988) also reported that with the increasing N levels to Palmarosa increased the nitrogen content and uptake. The results are in accordance with the findings of Rao *et al.* (1990) and Rajeswara Rao *et al.* (1991).

Combined effect

The combined application of FYM with NPK fertilizer doses (treatment T_7 to T_{12}), recorded significantly higher N uptake in both the years as compared to FYM doses and NPK doses applied alone. Among the combination treatments, the treatment receiving highest doses of FYM and NPK *i.e.* 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}) recorded the highest nitrogen uptake which was statistically significant over all other combination treatments (T_7, T_8, T_9, T_{10} and T_{11}), graded doses of NPK alone (T_4, T_5, and T_6), alone FYM doses (T_2, T_3 and T_{13}) and control (T_1) during both the years under study.

Pooled data showed that, among the treatments comprising of alone application of FYM, significantly highest N uptake (53.79 kg ha^{-1}) was recorded with the treatment T_{13} (100 kg N through FYM) which was at par with treatment T_3 (10 t FYM ha^{-1}). The highest N uptake (84.45 kg ha^{-1}) was noticed with the treatment T_6 (140:40:80 kg NPK ha^{-1}) among the graded doses of NPK. While in combination treatments, the treatment receiving 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}) was recorded significantly highest N uptake (112.74 kg ha^{-1}) than other combination treatments (T_7 to T_{11}), NPK

Table 2
N and P uptake by Java citronella as influenced by different treatments of nutrient management

	*Total N uptake (kg ha^{-1})***			*Total P uptake (kg ha^{-1})***		
Treatments	*2009-10*	*2010-11*	*Pooled mean*	*2009-10*	*2010-11*	*Pooled mean*
T_1 – Control	22.45	19.35	20.90	7.72	6.51	7.11
Organic manure doses (t ha^{-1})						
T_2 - 5 t FYM ha^{-1}	36.19	47.13	41.66	14.07	20.69	17.38
T_3 - 10 t FYM ha^{-1}	41.69	54.25	47.97	18.45	23.93	21.19
NPK fertilizer doses (kg ha^{-1})						
T_4 - 80:20:40 kg NPK ha^{-1}	68.51	73.28	70.89	30.28	32.27	31.27
T_5 - 100:30:60 kg NPK ha^{-1}	74.66	77.85	76.25	33.12	34.34	33.73
T_6 - 140:40:80 kg NPK ha^{-1}	84.43	84.46	84.45	37.02	36.90	36.96
Combined doses (O. M. + NPK fertilizer)						
T_7 - 5 t FYM + 80:20:40 kg NPK ha^{-1}	78.18	87.00	82.59	34.65	38.31	36.48
T_8 - 5 t FYM + 100:30:60 kg NPK ha^{-1}	85.77	91.47	88.62	38.07	39.82	38.95
T_9 - 5 t FYM + 140:40:80 kg NPK ha^{-1}	96.75	96.53	96.64	42.38	42.40	42.39
T_{10} -10 t FYM + 80:20:40 kg NPK ha^{-1}	88.24	102.23	95.24	38.27	44.46	41.37
T_{11} -10 t FYM + 100:30:60 kg NPK ha^{-1}	95.60	103.81	99.71	42.10	44.74	43.42
T_{12} -10 t FYM + 140:40:80 kg NPK ha^{-1}	109.46	116.02	112.74	48.08	50.25	49.17
Organic manure dose equivalent to 100 kg N ha^{-1}						
T_{13} -100 kg N through FYM (based on FYM analysis)	45.88	61.71	53.79	20.93	28.38	24.65
SE (m) ±	2.07	2.49	1.90	1.07	0.91	0.79
CD at 5 %	6.05	7.26	5.56	3.11	2.66	2.29

** Total N and P uptake of three cuttings of each year.

fertilizer doses (T_4 to T_6), FYM treatments (T_2, T_3 and T_{13}) and control (T_1). The two years data revealed that the N uptake was significantly increased due to different treatments of nutrient management except in control treatment.

Further, it was also observed that the highest N uptake by Java citronella was in the treatment of combined use of FYM + NPK *i.e.* with T_{12} (10 t FYM + 140:40:80 kg NPK ha^{-1}). This might be due to the combined application of FYM + NPK increased the dry matter yield as well as the nitrogen content which ultimately increased in the N uptake.

P Uptake

The data regarding the phosphorus uptake by Java citronella during 2009-10 and 2010-11 and its pooled data is presented in table 2.

Effect of organic manure (FYM)

From the foregoing observations it is seen that the highest P uptake (20.93 kg ha^{-1}) was observed with the treatment of 100 kg N through FYM (T_{13}) however, it was found at par with the treatment T_3 (10 t FYM ha^{-1}) in first year, whereas in second year the treatment T_{13} found statistically significant over other FYM treatments (T_2 and T_3) and control (T_1).

Effect of NPK fertilizer

Among sole application of NPK graded doses treatments, the treatment T_6 (140:40:80 kg NPK ha^{-1}) found significantly superior over treatments T_4 (80:20:40 kg NPK ha^{-1}), T_5 (100:30:60 kg NPK ha^{-1}) and T_1 (control) during both the years. Comparatively higher P uptake was recorded with the NPK treatments as compared to FYM treatments. The results are in agreement with findings of Barooah and Khader (1990) who also observed that addition of 40 kg P_2O_5 ha^{-1} increases significantly highest phosphorus content and stimulate bio synthesis of high energy phosphate compounds and uptake by Palmarosa was high after 45 days of application. Similarly, Wankhade *et al.* (2010[a]) also recorded favorable effects of N and P application @ 80 and 40 kg ha^{-1}, respectively on nutrient content and uptake (NP) by Palmarosa grown under Inceptisol.

Combined effect

Significantly highest P uptake was observed with the treatment T_{12} (10 t FYM + 140:40:80 kg NPK ha^{-1}) which was statistically significant over other combination treatments (*i.e.* T_7 to T_{11}), NPK fertilizer treatments (T_4, T_5 and T_6), FYM treatments (T_2, T_3 and T_{13}) and control (T_1).

It is observed from the two year pooled data that among alone application of FYM treatments (T_2, T_3 and T_{13}), the treatment consists of 100 kg N through FYM (T_{13}) recorded significantly highest P uptake (24.65 kg ha^{-1}) as compared to other FYM treatments. Similarly in respect of graded dose of NPK treatments (T_4, T_5 and T_6), the treatment T_6 (140:40:80 kg NPK ha^{-1}) recorded significantly highest P uptake (36.96 kg ha^{-1}) as compared to T_4 (80:20:40 kg NPK ha^{-1}), T_5 (100:30:60 kg NPK ha^{-1}) and T_1 (control). Further, in case of application of combination treatments (T_7 to T_{12}), the treatment comprised of higher dose of FYM with higher NPK dose *i.e.* 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}) recorded the significantly highest P uptake (49.17 kg ha^{-1}) than other combination treatments (T_7 to T_{11}).

The two year field experiment results revealed that, the P uptake by Java citronella was increased due to various treatments of nutrient management. Further, the highest P uptake was noticed in 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{-12}). Application of FYM and NPK resulted in higher uptake of phosphorus might be due to balanced nutrition resulted in to better accumulation of nutrients by the crop.

K Uptake

The data pertaining to potassium uptake by Java citronella during 2009-10 and 2010-11 as influenced by various treatments of nutrient management is presented in Table 3.

Effect of organic manure (FYM)

The application of FYM doses significantly increased the K uptake by Java citronella and significantly highest potassium uptake was recorded with the application of 10 t FYM ha^{-1} (T_3).

Table 3
K and S uptake by Java citronella as influenced by different treatments of nutrient management

	*Total K uptake (kg ha^{-1})***			*Total S uptake (kg ha^{-1})***		
Treatments	*2009-10*	*2010-11*	*Pooled mean*	*2009-10*	*2010-11*	*Pooled mean*
T_1 – Control	21.37	18.01	19.69	3.36	2.54	2.95
Organic manure doses (t ha^{-1})						
T_2 - 5 t FYM ha^{-1}	37.06	47.38	42.22	5.99	8.68	7.33
T_3 - 10 t FYM ha^{-1}	43.40	56.03	49.71	7.48	11.33	9.41
NPK fertilizer doses (kg ha^{-1})						
T_4 - 80:20:40 kg NPK ha^{-1}	72.07	76.14	74.11	10.65	11.57	11.11
T_5 - 100:30:60 kg NPK ha^{-1}	80.51	81.56	81.03	11.80	12.39	12.10
T_6 - 140:40:80 kg NPK ha^{-1}	91.63	90.15	90.89	15.67	15.07	15.37
Combined doses (O. M. + NPK fertilizer)						
T_7 - 5 t FYM + 80:20:40 kg NPK ha^{-1}	86.58	95.52	91.05	14.99	17.96	16.48
T_8 - 5 t FYM + 100:30:60 kg NPK ha^{-1}	96.26	100.49	98.38	16.67	19.55	18.11
T_9 - 5 t FYM + 140:40:80 kg NPK ha^{-1}	108.72	108.33	108.53	19.89	21.06	20.48
T_{10} -10 t FYM + 80:20:40 kg NPK ha^{-1}	97.76	112.09	104.93	17.59	21.63	19.61
T_{11} -10 t FYM + 100:30:60 kg NPK ha^{-1}	107.27	114.34	110.81	19.40	23.39	21.39
T_{12} -10 t FYM + 140:40:80 kg NPK ha^{-1}	126.79	133.82	130.31	23.67	27.86	25.77
Organic manure dose equivalent to 100 kg N ha^{-1}						
T_{13} -100 kg N through FYM (based on FYM analysis)	48.56	66.81	57.68	8.93	13.96	11.45
SE (m) ±	2.21	2.62	1.77	0.47	0.57	0.44
CD at 5 %	6.44	7.65	5.16	1.36	1.67	1.29

** Total K and S uptake of three cuttings of each year.

Further, it is noticed that the application of higher dose of FYM equivalent to 100 kg N (T_{13}) recorded comparatively higher uptake of K than 5 and 10 t FYM ha^{-1}, however the statistically significant was reported during second year and in pooled data. The higher potassium availability with FYM application might have lead to better root development, improved metabolism, improved nutrient supply might have resulted in better growth of the plants and in turn enhanced the dry matter accumulation. As the dry matter accumulation increases, the potassium uptake in the plants also increases.

Effect of NPK fertilizer

Alone application of NPK graded doses also found to increase the K uptake during both the years under study. Further, it is noticed that the K uptake was increased with each increment of graded dose of NPK and significantly highest K uptake was noticed with 140:40:80 kg NPK ha^{-1} application (T_6). Increasing potassium level to Palmarosa crop increased the potassium content and uptake reported by Chinnamma *et al.* (1988), Wankhade *et al.* (2010[a]) also reported favorable effect of nitrogen and phosphorus application @ 80 and 40 kg ha^{-1}, respectively on nutrient content and uptake (NPK) by Palmarosa grown under Inceptisol.

Combined effect

The data revealed that K uptake was further enhanced due to combined application of FYM with NPK graded doses and significantly highest K uptake was noticed with the application of 10 t FYM

+ 140:40:80 kg NPK ha^{-1} (T_{12}). This might be due to the combined application of FYM along with NPK increases the yield of the crops by uniform supply of nutrients to all stages of plant growth, enhanced moisture availability due to better soil structure, resulted in increasing nutrient availability, these helps in better translocation of water and increased the nutrient uptake.

On the perusal of the pooled data it is seen that among FYM doses, the treatment T_{13} (100 kg N through FYM) recorded significantly higher uptake of K (57.68 kg ha^{-1}) as compared to treatment T_2 (5 t FYM ha^{-1}) and T_3 (10 t FYM ha^{-1}), while among the NPK graded fertilizer treatments, the treatment T_6 (140:40:80 kg NPK ha^{-1}) recorded higher uptake of K (90.89 kg ha^{-1}) as compared to T_4 (80:20:40 kg NPK ha^{-1}) and T_5 (100:30:60 kg NPK ha^{-1}). In combination treatments, the treatment T_{12} (10 t FYM + 140:40:80 kg NPK ha^{-1}) recorded higher uptake of K (130.31 kg ha^{-1}) as compared to all other combination treatments *i.e.* T_7 to T_{11}. The overall result revealed that the K uptake by Java citronella was comparatively more during the second year of the crop.

S Uptake

The data in respect of sulphur uptake by Java citronella recorded during both the years under study is presented in table 3.

Effect of organic manure (FYM)

The data revealed that the S uptake by Java citronella was found to increase with each increment of FYM and the highest sulphur uptake was noted with the application of 10 t FYM ha^{-1} (T_3). However, the application of higher dose of FYM (equivalent to 100 kg N) than 10 t FYM ha^{-1} further enhanced the S uptake by the plants during both years under study.

Effect of NPK fertilizer

The data showed that the S uptake was significantly higher with NPK doses than the uptake recorded with the FYM alone application treatments (T_2 and T_3). Further, it is noticed that the S uptake found to increase with each increment of NPK dose and significantly highest sulphur uptake was noticed with the application of 140:40:80 kg NPK ha^{-1} (T_6) as compared to treatments T_4 and T_5, these treatments (T_4 and T_5) were statistically at par in respect of S uptake.

Combined effect

The data further indicated that the S uptake was further enhanced with the application of FYM doses along with NPK graded doses. Further, it was noticed that the sulphur uptake was found to increase with each increment of combined application and significantly highest S uptake was noticed with the application of 10 t FYM along with 140:40:80 kg NPK ha^{-1} (T_{12}). Increased in sulphur uptake in these treatments might be due to better availability of sulphur in soil and increased dry matter yield.

The pooled result also indicated that among the FYM application treatments, the treatment comprising of FYM dose equivalent to 100 kg N (T_{13}) recorded significantly highest sulphur uptake (11.45 kg ha^{-1}) as compared to 5 and 10 t FYM ha^{-1}. The higher S uptake recorded with this treatment might be due to the more availability of nutrients from comparatively higher dose as compared to 5 and 10 t FYM ha^{-1}. The alone application of graded doses of NPK also influenced the S uptake and significantly highest sulphur uptake (15.37 kg ha^{-1}) was recorded with the application of 140:40:80 kg NPK ha^{-1} (T_6). The S uptake further enhanced due to the combined application of FYM and NPK fertilizer and significantly highest S uptake (25.77 kg ha^{-1}) by Java citronella was recorded with 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}).

CONCLUSION

From the results, it can be concluded that the conjunctive use of FYM along with chemical fertilizer (10 t FYM + 140:40:80 kg NPK ha^{-1}) was found beneficial way of nutrient management for improving uptake of macro nutrients (N, P, K and S) by Java citronella.

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