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Uptake of Micro Nutrients by Java Citronella as Influenced By Different Treatments Of Nutrient Management Under Inceptisols

S.P. Nandapure[1], S.R. Imade[2], R.V. Mahajan[3], S.M. Jadhao[4] and S.G. Wankhade[5]
Department of Soil Science & Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola - 444 104, Maharashtra, India
E-mail: sachin.nandapure@gmail.com

ABSTRACT
A Field study was conducted during kharif 2009-10 and 2010-11 at Nagarjun Medicinal and Aromatic Plants Garden, Dr. PDKV, Akola (M.S.), India. The experimental field 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). The outcomes suggested that concrete improvement in Fe, Mn, Zn and Cu uptake was noticed with combined application of FYM + NPK (10 t FYM + 140:40:80 kg NPK ha^{-1}).Therefore, this study helped to establish the fact that the combined application of FYM with chemical fertilizer (10 t FYM + 140:40:80 kg NPK ha^{-1}) was found beneficial way of nutrient management for improving the uptake of micro nutrients (Fe, Mn, Zn and Cu) by Java citronella.
Key words: *Java citronella, Nutrient management, Inceptisol and Uptake of Micro Nutrients.*

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INTRODUCTION

Java citronella is a tropical plant that originated in Sri Lanka. However, nowadays, it is popularly farmed in Indonesia, China and India, in addition to Sri Lanka. This plant belongs to the Graminae family and is botanically known as *Cymbopogon winterianus*. In India, it is mainly cultivated in the tea gardens of Assam. The states of Uttar Pradesh., Maharashtra, Karnataka, Gujarat, Manipur, Meghalaya, Tamil Nadu, Nagaland, Uttaranchal, Andhra Pradesh and Tripura also cultivate this plant, but to a lesser expanse. The commercial cultivation of this plant is for its oil, which is obtained by distillation (Shiva et al., 2002).

Java citronella is cultivated in India to a great extent. The area under cultivation is 9000 ha. Annually, 1600 tons of Java citronella is produced in the world. India alone is responsible for the production of 500 tones. India ranks 3rd in the world for the manufacturing of essential oils. Java citronella is one the most important essential oil produced by India. Maharashtra is one of the leading states for Java citronella production. Around 320 ha of agriculture land is employed for this purpose in this state. Annually, Maharashtra produces 25 ton of oil. In Maharashtra, the Vidharbha area alone is responsible for 56.4 ha of cultivation. The foremost districts in Maharashtra where this crop is planted are Nagpur, Yavatmal, Akola, Wardha, Chandrapur and Amravati. Until 2025, the worldwide requirement of this crop is anticipated to be 66000 ha, with India having a market demand up to 3200 ha. Therefore, this is an advantageous opportunity for farmers to exploit. Maharashtra intends to expand Java citronella cultivation up to 1600 ha, and simultaneously increase its oil production by 480 tons. Currently, the gaining cost of citronella oil and its value-added products is around 325-350 Rupees per kg. Hydroxyl citronellol has a gaining cost of 1150 Rupees per kg. The requirement of Java citronella is projected to be around 120-130 tons per year (Anonymous, 2004), which is a promising hope to the farmers of the crop.

The oil of Java citronella is aromatic and is, therefore, predominantly used by the perfume industry in small quantities. In addition, this oil is used directly as well as indirectly in soaps, soap flakes, cosmetics, detergents, incense sticks, insecticides, *etc.* However, citronellal is mainly employed as a starting raw material to derive other value-added products, such as mosquito repellants. The discarded citronella grass is a suitable raw material for cellulose pulp and paper production with the help of sulphate, sulphite and cold caustic soda.

However, Java citronella cultivation is known to drain the soil of its nutrients. Therefore, appropriate soil management with nutrient amendments is indispensable for maintaining the elevated economic crop yield. These measures also help in retaining soil fertility. The measures employed show that the biomass content of crop and nutrient levels of soil improved significantly after just five months. Furthermore, maximum biomass of crop and maximum nutrient uptake was observed after ten months of crop cultivation (Prakasa Rao and Ganesha Rao, 1986).

No field studies have been conducted in the Vidarbha region to explore the nutrient management techniques used for Java citronella cultivation under the prevalent agro-climatic environment. Therefore, present investigation was carried out to understand the exact nutrient removal pattern by Java citronella in Inceptisol soils of Vidarbha region of Maharashtra.

MATERIAL AND METHODS

Study site and Treatment Features

The experiment was conducted during *Kharif* seasons of 2009-10 and 2010-11 at Nagarjun Medicinal Plants Garden, Dr. PDKV, Akola (latitude of 22^0 41' N and longitude of 77^0 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 42.6^0C during summer and minimum as low as 10.3^0C during winter. The annual average rainfall of area is 764.7 mm. The soil of the experimental field was medium black, Smectitic, clay loam in texture and classified as *Typic Haplustept* which comes under the soil order Inceptisol. The initial soil analysis indicated that, the soil was calcareous in nature and moderately alkaline in reaction. In case of physical properties the soil was low in hydraulic conductivity and available water capacity. 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. 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.

Sowing and Harvesting

The study started on 7th July 2009, when Java citronella 'Bio-13' plantlets were planted (rooted slips @ 16666 slips ha^{-1}**)**. A spacing of 90 x 60 cm was maintained between each planting. The plantlets were irrigated soon after transplantation and thereafter as and when needed during the experiment. Java citronella was harvested by cutting the leaf blade at its base, i.e., approximately 10-12 cm above the ground. During the two seasons of the study, the crop was harvested 6 times.

Plant Sample Processing and Analysis

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 65^0C 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 micronutrients content in leaves was determined and uptake was computed by multiplying the respective nutrient concentration in per cent by dry matter at each cutting. Processed plant samples were analyzed for determination of total micronutrients content (Fe, Mn, Zn and Cu) from di-acid extract by using atomic absorption spectrophotometer (Issac and Kerber, 1971).

Statistical Analysis

Statistical analysis was conducted according to the method of 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 was 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. 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*. (1991[a]).

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 (1987[d]).

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).

Fe uptake

The data pertaining to Fe uptake by Java citronella recorded during both the years and its pooled data was presented in table 2.

Effect of organic manure (FYM):

Considering the application of FYM at different doses, the treatment comprised of higher dose of FYM to meet 100 kg N through FYM (T_{13}) recorded the maximum Fe uptake than control (T_1) and other FYM treatments i.e. T_2 and T_3. However, the level of significance was noticed with the Fe uptake recorded during second year and in pooled means.

Effect of NPK fertilizer:

The application of NPK fertilizer at different graded significantly increased the Fe uptake with every addition of graded dose. Significantly highest Fe uptake was recorded with the treatment of 140:40:80 kg NPK ha^{-1} (T_6) as compared to the Fe uptake recorded with the treatments T_4 and T_5 further, it is noticed that the Fe uptake was significantly more with the alone application of NPK graded doses than FYM doses.

Combined effect:

Significantly maximum Fe uptake by Java citronella was noticed in the combined treatment of FYM @ 10 t + NPK @ 140:40:80 kg ha^{-1} (T_{12}) over rest of all other treatments. Comparatively higher uptake of Fe was recorded with the plants which received FYM along with NPK than the uptake noticed with alone application of FYM or NPK fertilizer.

When pooled analysis carried for two years, it is seen that, in FYM treatments, the maximum Fe uptake (1437.20 g ha^{-1}) was found in treatment T_{13} (100 kg N through FYM) as compared to other FYM treatments (T_2 and T_3) While, in case of NPK graded doses treatments, the treatment T_6 (140:40:80 kg NPK ha^{-1}) recorded maximum value of Fe uptake (2036.43 g ha^{-1}) than other NPK treatments (T_4 and T_5), however, the application of FYM + NPK in integrated manner significantly highest Fe uptake (2679.08 g ha^{-1}) was noticed with the treatment T_{12} (FYM @ 10 t + NPK @ 140:40:80 kg ha^{-1}) than rest of all other treatments.

Mn uptake

The data in respect of Mn uptake was recorded during 2009-10, 2010-11 and its pooled effect was presented in table 2.

Effect of organic manure (FYM):

It is evident from the data, among the treatments comprising of different doses of FYM application, the treatment 100 kg N through FYM (T_{13}) was found to be superior in respect of Mn uptake over the treatment T_2 (5 t FYM ha^{-1}) and T_1 (control) however, it was found statistically at par with treatment T_3 (10 t FYM ha^{-1}) during both the years.

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 Mn uptake (431.10 g ha^{-1}) than T_1 (control), T_4 (80:20:40 kg NPK ha^{-1}) and T_5 (100:30:60 kg NPK ha^{-1}) during the first year, whereas, in the second year the treatment T_6 was found at par with treatment T_5.

Combined effect:

The data revealed that Mn uptake was further enhanced due to combined application of FYM with NPK graded doses and significantly highest Mn uptake was noticed with the application of 10 t FYM in combination with 140:40:80 kg NPK ha^{-1} (T_{12}) than all the other treatments of combined application of FYM + NPK treatments (T_7 to T_{11}) during both the years of study. This might be due to beneficial effect of FYM along with NPK which increases the availability of Mn in these treatments and dry matter accumulation, ultimately resulted in increased uptake of Mn.

Pooled data of two years in respect of Mn uptake revealed that the sole application of 100 kg N through FYM on the basis of analysis for N content (T_{13}) recorded the highest Mn uptake (301.82 g ha^{-1}) but it was found at par with FYM @ 10 t ha^{-1} (T_3). The NPK graded fertilizer doses treatments, the treatment T_6 (140:40:80 kg NPK ha^{-1}) significantly recorded maximum uptake of Mn (427.67 g ha^{-1}) than treatments T_4 (80:20:40 kg NPK ha^{-1}) and T_5 (100:30:60 kg NPK ha^{-1}). From the data it is seen that the Mn uptake was found highest (562.62 g ha^{-1}) with the treatment of 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}) than rest of all other treatments.

Zn uptake

The data in respect to Zn uptake by Java citronella recorded during 2009-10 and 2010-11 and its pooled data was presented in table 3.

Effect of organic manure (FYM):

Among the alone application of FYM treatments, the treatment comprising of 100 kg N through FYM (T_{13}) recorded the highest Zn uptake (159.80 g 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 uptake of Zn (220.38 g ha^{-1}) as compared to 5 t (T_2) and 10 t FYM ha^{-1} (T_3).

Effect of NPK fertilizer:

Application of NPK fertilizer at different graded significantly increased the Zn uptake with every addition of graded dose. Significantly highest Zn uptake (271.62 g ha^{-1}) was recorded with the treatment of 140:40:80 kg NPK ha^{-1} (T_6) as compared to the Zn uptake recorded with the treatments T_4 and T_5 during the first year of experimentation whereas, in the second year it was at par with treatment T_5 (100:30:60 kg NPK ha^{-1}). Further, it is noticed that the Zn uptake was significantly more with the alone application of NPK graded doses than FYM doses.

Combined effect:

The combined application of FYM with NPK fertilizer doses (treatment T_7 to T_{12}), recorded significantly higher Zn 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 Zn uptake which was statistically highly 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. Application of FYM along with NPK increases the availability of Zn in the soil solution which is readily absorbed by the plant, might be the reason for increased in Zn uptake.

The pooled data showed that among the FYM treatments, the application of FYM to meet 100 kg N on the basis of nitrogen analysis (T_{13}) recorded the significantly highest Zn uptake (190.09 g ha^{-1}) than other FYM treatments (T_2 and T_3) and control (T_1). Amongst the NPK graded doses treatments, the treatment T_6 (140:40:80 kg NPK ha^{-1}) recorded significantly highest Zn uptake (263.81 g ha^{-1}) as compared to other NPK fertilizer treatments (T_4 and T_5), FYM treatments (T_2, T_3 and T_{13}) and control (T_1). The combination treatment, T_{12} (10 t FYM + 140:40:80 kg NPK ha^{-1}) recorded the significantly maximum Zn uptake (354.74 g ha^{-1}) than rest of all the other treatments.

Cu uptake

The data pertaining to Cu uptake by Java citronella recorded during both the years under study was presented in table 3.

Effect of organic manure (FYM):

From the foregoing observations it is seen that the highest Cu uptake (13.25 g ha^{-1}) was observed with the treatment of 100 kg N through FYM (T_{13}) however it was found at par with treatment T_3 (FYM @ 10 t ha^{-1}) and treatment T_2 (FYM @ 5 t ha^{-1}) in first year, whereas in second year the treatment (T_{13}) found statistically significant over other FYM treatments and control.

Effect of NPK fertilizer:

The data showed that the Cu uptake was significantly higher than the uptake recorded with the FYM alone application treatments (T_2 and T_3). Further, it is noticed that the Cu uptake found to increase with each increment of NPK dose and significantly highest Cu uptake (22.42 g ha^{-1}) was noticed with the application of 140:40:80 kg NPK ha^{-1} (T_6) as compared to treatments T_1 (control), T_4 (80:20:40 kg NPK ha^{-1}) and T_5 (100:30:60 kg NPK ha^{-1}), these treatments (T_4 and T_5) were statistically at par in respect of uptake of Cu during the first year. However, in the second year the significantly higher Cu uptake (21.36 g ha^{-1}) was noted with same treatment (T_6) as compared to control (T_1) but, it was at par treatment T_5.

Combined effect:

Significantly maximum Cu uptake by Java citronella was observed in the combined treatment of 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}) over rest of all other treatments. Comparatively higher uptake of Cu was recorded with the plants which received FYM along with NPK than the uptake noticed with alone application of FYM or NPK fertilizer, might be due to balanced availability of Cu from soil to the plant which ultimately resulted in increased uptake of Cu.

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 Cu uptake (15.81 g ha^{-1}) as compared to 5 and 10 t FYM ha^{-1}. The higher Cu uptake recorded with this treatment might be due to the more availability of nutrients from comparatively higher dose (15 t ha^{-1}) as compared to 5 and 10 t FYM ha^{-1}. The alone application of graded doses of NPK also influenced the Cu uptake and significantly highest Cu uptake (21.89 g ha^{-1}) was recorded with the application of 140:40:80 kg NPK ha^{-1} (T_6). Comparatively highest Cu uptake was noted with NPK treatments than FYM alone application. The Cu uptake further enhanced due to the combined application of FYM and NPK fertilizer and significantly highest Cu uptake (29.45 g ha^{-1}) by Java citronella was recorded with 10 t FYM + 140:40:80 kg NPK ha^{-1} (T_{12}).

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

Table 2. Fe and Mn uptake by Java citronella as influenced by different treatments of nutrient management						
Treatments	**Total Fe uptake (g ha^{-1})****			**Total Mn uptake (g ha^{-1})****		
	2009-10	**2010-11**	**Pooled mean**	**2009-10**	**2010-11**	**Pooled mean**
T_1 – Control	586.5	495.7	541.1	123.16	104.12	113.64
Organic manure doses (t ha^{-1})						
T_2 - 5 t FYM ha^{-1}	955.9	1264.6	1110.2	200.75	265.54	233.15
T_3 - 10 t FYM ha^{-1}	1096.0	1477.5	1286.7	230.18	310.26	270.22
NPK fertilizer doses (kg ha^{-1})						
T_4 - 80:20:40 kg NPK ha^{-1}	1664.8	1735.9	1700.3	349.59	364.47	357.03
T_5 - 100:30:60 kg NPK ha^{-1}	1808.7	1841.0	1824.8	379.75	386.61	383.18
T_6 - 140:40:80 kg NPK ha^{-1}	2052.9	2020.0	2036.4	431.10	424.24	427.67
Combined doses (O. M. + NPK fertilizer)						
T_7 - 5 t FYM + 80:20:40 kg NPK ha^{-1}	1916.1	2182.2	2049.2	402.40	458.27	430.33
T_8 - 5 t FYM + 100:30:60 kg NPK ha^{-1}	2104.0	2281.8	2192.9	441.86	479.16	460.51
T_9 - 5 t FYM + 140:40:80 kg NPK ha^{-1}	2321.3	2343.2	2332.2	487.50	492.92	490.21
T_{10} -10 t FYM + 80:20:40 kg NPK ha^{-1}	2149.0	2468.8	2308.9	451.28	518.43	484.85
T_{11} -10 t FYM + 100:30:60 kg NPK ha^{-1}	2333.8	2540.9	2437.3	490.12	533.61	511.87
T_{12} -10 t FYM + 140:40:80 kg NPK ha^{-1}	2583.4	2774.8	2679.0	542.53	582.70	562.62
Organic manure dose equivalent to 100 kg N ha^{-1}						
T_{13} -100 kg N through FYM (based on FYM analysis)	1207.7	1666.7	1437.2	253.61	350.02	301.82
SE (m) ±	58.13	51.20	39.50	14.58	15.04	13.79
CD at 5 %	169.64	149.42	115.28	42.55	43.90	40.24

** Total Fe and Mn uptake of three cuttings of each year

Table 3. Zn and Cu uptake by Java citronella as influenced by different treatments of nutrient management						
Treatments	**Total Zn uptake (g ha^{-1})****			**Total Cu uptake (g ha^{-1})****		
	2009-10	**2010-11**	**Pooled mean**	**2009-10**	**2010-11**	**Pooled mean**
T_1 – Control	77.59	64.34	70.96	6.40	5.37	5.88
Organic manure doses (t ha^{-1})						
T_2 - 5 t FYM ha^{-1}	126.44	164.12	145.28	10.43	13.53	11.98
T_3 - 10 t FYM ha^{-1}	144.99	191.75	168.37	11.97	15.84	13.90
NPK fertilizer doses (kg ha^{-1})						
T_4 - 80:20:40 kg NPK ha^{-1}	220.27	221.81	221.04	18.15	18.31	18.23
T_5 - 100:30:60 kg NPK ha^{-1}	239.26	234.81	237.03	19.74	19.65	19.69
T_6 - 140:40:80 kg NPK ha^{-1}	271.62	256.00	263.81	22.42	21.36	21.89
Combined doses (O. M. + NPK fertilizer)						
T_7 - 5 t FYM + 80:20:40 kg NPK ha^{-1}	253.51	283.45	268.48	20.94	23.53	22.23
T_8 - 5 t FYM + 100:30:60 kg NPK ha^{-1}	278.34	296.24	287.29	22.98	24.71	23.84
T_9 - 5 t FYM + 140:40:80 kg NPK ha^{-1}	307.12	305.26	306.19	25.32	25.46	25.39
T_{10} -10 t FYM + 80:20:40 kg NPK ha^{-1}	284.31	327.38	305.84	23.43	27.24	25.33
T_{11} -10 t FYM + 100:30:60 kg NPK ha^{-1}	308.74	335.99	322.37	25.44	28.02	26.73
T_{12} -10 t FYM + 140:40:80 kg NPK ha^{-1}	341.75	367.73	354.74	28.17	30.74	29.45
Organic manure dose equivalent to 100 kg N ha^{-1}						
T_{13} -100 kg N through FYM (based on FYM analysis)	159.80	220.38	190.09	13.25	18.38	15.81
SE (m) ±	6.88	7.55	4.15	0.56	0.74	0.51
CD at 5 %	20.07	22.05	12.11	1.61	2.17	1.50

** Total Zn and Cu uptake of three cuttings of each year

CONCLUSIONS

This study helped to establish the fact that the combined application of FYM with chemical fertilizer (10 t FYM + 140:40:80 kg NPK ha^{-1}) improved the availability of micro nutrients in the soil, thereby facilitating the sustainment of soil fertility and finally uptake of micro nutrients (Fe, Mn, Zn and Cu) by Java citronella.

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