International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 896-901

Received: 28-05-2019
Accepted: 30-06-2019

P Venkata Subbaiah
Assistant Professor,
Department of Soil Science & Agricultural Chemistry,
Agricultural, College, Bapatla, Andhra Pradesh, India

YS Satish Kumar
Scientist (Soil Science, Agricultural Chemistry),
Regional Agricultural Research Station, Nandyal,
Andhra Pradesh, India

Correspondence
P Venkata Subbaiah
Assistant Professor,
Department of Soil Science & Agricultural Chemistry,
Agricultural, College, Bapatla, Andhra Pradesh, India

Review on effect of inorganic and organic sources of nutrients and their integrated use on growth and yield of maize (*Zea mays* L.)

P Venkata Subbaiah and YS Satish Kumar

Abstract
No single source of fertilizer is capable of supplying all essential plant nutrients in adequate amounts and in balanced proportion for optimum growth, yield and quality of crops. Therefore, it is inevitable to integrate plant nutrient supply through combined use of organic manures and inorganic sources of fertilizers. Crop responses to organic and biological nutrient sources are not as effective as that of fertilizers but the combined use of such sources is known to enhance the utilization efficiency of applied fertilizers besides improving the physico-chemical properties of soil and preventing the emerging micronutrient deficiencies. Integrated nutrient management improves soil productivity on long term basis through appropriate use of fertilizers and organic manures. Their scientific management results in optimum growth, yield, quality and uptake of maize at different agro ecological situations.

Keywords: Organic nutrients, inorganic nutrients, integrated nutrients, maize, growth, yield

Introduction
Maize being a C_4 plant and is highly productive crop and has diversified uses mainly as food and feed for livestock. Globally 67 per cent of maize is used for livestock feed, 25 per cent for human consumption, industrial purpose and balance is mostly for seed purpose. In India, currently 55% of the maize grains produced are used for food purposes, 14% for the livestock feed, 18% for poultry feed, 12% for starch and 1% for seed. The mature kernel contains 70-75% starch, 8-10% protein and 4-5% oil. The success of crop production is mainly influenced by weather and soil nutrient status. Different fertility levels of soils also significantly influence the yields of the maize crop in terms of cobs or grains. Integrated use of fertilizers and organic manures help in maintaining yield stability in most of the agro ecosystems through correction of secondary and micronutrient deficiencies, enhancing the efficiency of applied nutrients and providing favourable soil physical conditions.

Effect of Inorganic Sources of Nutrients on Maize
Dry matter production, grain and stover yield
Maize is a nutrient exhaustive crop. Its demand for nitrogen is more than any other nutrient followed by phosphorus. Nitrogen increases the shoot growth while phosphorus increases root development. Application of phosphorus in conjunction with nitrogen improved the available N status of soil as compared to the application of nitrogen alone. There is a need to restore the soil fertility and improve the crop productivity through appropriate manipulation of nutrient supply to a particular crop. This warrants a thorough understanding of the nutrient requirement of different crops and cropping systems in different ecological, edaphic and variable environments. To this effect, literature available on the N and P requirements of maize in different soils of variable texture and physico-chemical properties during the *kharif* season is reviewed.
Kumpawat and Rathore (1995) [19] reported that *kharif* maize grown on sandy loam soils of Rajasthan required 120 kg N ha^{-1} to produce maximum grain and stover yield. The soil was low in organic carbon, medium in available P and K while, the pH was 7.9. A later investigation on a soil of similar texture at Kullu in Himachal Pradesh by Parmar and Sharma (2001) [29] also confirmed that the nitrogen requirement of maize was 120 kg N ha^{-1} in the soil of low status in available N, medium in available P and high in available K having an acidic

Reaction. This level of N requirement was also considered ideal for the sandy loam soil of Meghalaya having an acidic reaction with low status of available N and P and moderate level of available K to maximize the grain and fodder yield of *kharif* maize (Panwar and Munda, 2006) [28]. The need to apply 120 kg N per hectare to realize maximum dry matter production of maize in *kharif* in acidic soil of sandy loam texture holding low level of organic carbon and available N and medium P and K in the sub humid agro climatic zone of Orissa was confirmed by Anita *et al.*(2007) [3]. The response to nitrogen application have increased up to 150 kg ha^{-1} resulting in maximum grain and stover yield of *kharif* maize in alkaline sandy loam soil of New Delhi which had low organic carbon and available N and medium P and K status (Benerjee and Singh, 2003) [6]. A further higher level of 180 kg N was required in an acidic red sandy loam soil of Orissa (Sahoo and Mahapatra, 2004) [38]. Working on the nutrient schedule Singh *et al.*, 2009 reported that maize required 110 kg N, 90 kg P_2O_5 and 70 kg K_2O ha^{-1} in such a soil of Ranchi having acidic reaction, medium in organic carbon, low in available P and rich in available K.

The phosphorus requirement of maize was ascertained to be 26.4 kg P ha^{-1} to produce maximum dry matter, grain and stover yield in sandy loam soil with neutral reaction, low organic carbon, total N and P and medium in available K at New Delhi (Jat and Ahlawat, 2004) [13].

Singh *et al*. (2000) [4-41] reported that the nutrient requirement to harvest maximum grain and stover yield of *kharif* maize was 120 kg N and 90 kg P_2O_5 ha^{-1} in the sandy loam soils of Delhi having low organic carbon, available N, P and medium available K content.

Working on the requirement of major nutrients. Verma *et al.* (2003) observed that the crop required 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in sandy loam soils of Kanpur having an alkaline reaction, medium organic carbon, low status of available P and K. A fine loamy soil at Bangalore having medium organic carbon, low available N and high in available P required 100 kg N, 75 kg P_2O_5 and 50 kg K_2O ha^{-1} (Mohamoud and Sharanappa, 2002) [24-25]. In an earlier investigation Mohamoud *et al.* (2002) [24-25] observed that the crop responded to produce more dry matter, seed and stover yield in response to the application of these nutrients at the rate of 150-75-50 kg ha^{-1}.

The experiment conducted on sandy clay loam soils showed wide range in the nitrogen requirement of maize. Vadivel *et al.* (1999) [47] recorded a significant response to dry matter production on application of 60 kg N ha^{-1} in a soil slightly alkaline, low in organic carbon and available N, but medium in available P and high in available K. Contrary to this, Rohitashav *et al.* (1995) [37] and Singh *et al.* (1995) [37-42] recorded significant response to increasing level of fertilizer up to 120 kg N ha^{-1} to increase the dry matter production at Palampur in Himachal Pradesh. High nutrient requirement to the extent of 250 kg N, 125 kg P_2O_5 and 125 kg K_2O ha^{-1} was reported to increase the grain and stover yield of maize in the sandy clay loam texture soil at Coimbatore having low available N, medium available P and high available K (Srikanth *et al.*,2009) [45].

The alkaline clayey soils of Gujarath (Meena *et al.*, 2007) [23] and at Guntur in Andhra Pradesh (Bharathi, 2004) [7] recorded increased dry matter, grain and stover yield of maize on application of 120 kg N ha^{-1}. Ramesh *et al.* (2008) [33] reported that the alkaline clayey soil having medium organic carbon low available N, medium available P and high available K at Bhopal produced maximum maize grain yield on application of 100 kg N, 50 kg P_2O_5 and 30 kg K_2O ha^{-1}.

The need for a revision and enhancement in the level of recommended dose of fertilizer nutrients to maize was investigated. Anil Kumar *et al.* (2002) [2] and Verma *et al.* (2006) [50] recorded substantial improvement in the productivity of maize by rescheduling the recommended level by 150%. Reddy *et al.* (2010) [21-35] on the other hand observed that the increase in the level of fertilizers by 200% over the recommendation was more productive.

The review indicated that there was no consistency in the fertilizer requirement of maize in the *kharif* season within a given texture and soil available nutrient status. Therefore, it is apt that the fertilizer schedule be site specific and system based.

Nutrient concentration and uptake

Nutrient uptake refers to the total amount of nutrients taken by a crop during the period of growth. Nutrient removal by the crops depends on the plant parts which are harvested, their composition and their share in total dry matter production. Actual removal will vary with crop yield, crop variety, soil fertility and level of management. The uptake values, therefore, would provide a reliable estimate of the nutrient requirements under varying soil and climatic situations. However, accurate removals can only be determined by laboratory analysis. In general, the uptake of nutrients by maize increases with increasing levels of nutrients applied through fertilizers. The relevant literature pertaining to the effect of inorganic sources of nutrients on N, P and K uptake by maize in different soil types is reviewed hereunder.

Arya and Singh (2000) [4-41] reported that the application of 120 kg N ha^{-1} to maize grown on sandy loam soil having low organic carbon, total N, available P and medium available K recorded the highest uptake of N, P, K and Zn both in grain and stover at IARI, New Delhi. A similar type of soil also recorded maximum uptake of N, P and K by maize with the application of 120 kg N ha^{-1} at Kullu, Himachal Pradesh (Parmar and Sharma,2001) [29]. This level of N requirement was also considered ideal for the sandy loam soils of Meghalaya to obtain maximum uptake of N by maize (Panwar and Munda, 2006) [28]. Similar response in N uptake on sandy loam soils to the application of 120 kg N ha^{-1} was also recorded by Anita *et al.* (2007) [3]

In a slightly alkaline sandy clay loam soil the uptake of N, P and K was increased on the application of 60 kg N ha^{-1} to maize at Coimbatore. This soil was low in organic carbon, available N, medium in available P and high in available K (Vadivel *et al.*, 1999) [47]. The nutrient uptake studies conducted by Verma *et al.* (2006) [50] at Udaipur in Rajasthan showed that the maize took up more N, P and K on increasing the level of fertilizer application to 150% of the recommended dose in soil rich in available nutrients.

Quality Parameters

Protein Content and Protein yield

Maize seeds are rich in carbohydrates, proteins and certain minerals. However, the nutritional quality of maize protein is poor mainly due to low digestibility. In general protein content in maize cultivars ranged from 8.1 to 11.5 per cent (Sorte *et al.*, 2005) [44]. However N and P levels had synergistic effect on protein content. The maximum protein content and yield in maize in response to nutrient application rates reported in literature is reviewed.

Application of 120 kg N and 90 kg P_2O_5 per hectare in a sandy loam soil having low organic carbon, available N and P and medium available K recorded maximum protein yield of *kharif* maize grown at IARI, New Delhi (Arya and Singh, 2000) [4-41]. Similar results of higher protein content and protein yield was also reported by Anita *et al.* (2007) [3] with same level of nutrient application under similar type of soil conditions in sub humid agro climate of Orissa. But, Tank *et al.* (2006) [46] obtained more protein content with increasing level of fertilizer up to 180 kg N ha^{-1} in the soil which was detected to be low in available N, medium in available P and high in available K.

Variable responses to variable rate of fertilizer application in soils having a loamy sand texture were recorded in investigations. The protein yield increased significantly on application of 80 kg N ha^{-1} at Bhubaneswar where the soil was low in organic carbon and available N but medium in available P and K (Kar *et al.*, 2006). Contrary to this finding, Khadtare *et al.* (2006) [16] observed that the soil of similar texture and nutrient status in Gujarat produced more protein on application of 150 kg N and 50 kg P_2O_5 ha^{-1}.

Singh *et al.* (1995) [37-42] recorded a positive response to an increase in the level of fertilizer up to 120 kg N ha^{-1} to maximize the percent crude protein in the maize kernel and crude protein yield in silty clay loam soil having a medium status in available N and P but poor in available K. The silty clay loam soil measuring low available N, medium available P and high available K at Coimbatore required a higher fertilizer dose of 250 kg N, 125 kg P_2O_5 and 125 kg K_2O ha^{-1} to maximize protein percent in maize kernels (Srikanth *et al.*, 2009) [45]. On the other hand, Rohitashav singh *et al.*(1995) [37-42] in an earlier investigation observed that the clay loam soil high in organic carbon, medium in available N and P but low in available K required 120 kg N ha^{-1} to increase the protein percent and its yield.

In a slightly alkaline clayey soil application of 120 kg N per hectare recorded maximum protein content in maize at Gujarat by Meena *et al.* (2007) [23]. Ramesh *et al.* (2008) [33] also reported that the application of 100 kg N, 50 kg P_2O_5 and 30 kg K_2O ha^{-1} recorded maximum protein content on similar soil texture having medium organic carbon, low available N, medium P and high in available K at Bhopal.

Oil content and yield

Maize is not usually classified as an oilseed, but looking to its large acreage and high yield, development of maize genotypes possessing high oil content will be a step as a long term measure for increasing the availability of edible oil from nontraditional sources of oils to bridge the demand – supply gap. Corn oil, a by – product resulting from the processing of maize seed for extraction of starch contains predominantly >88% essential PUPAs like Oleic and Linoleic acids, Thus has received wide attention as a edible oil and made corn oil nutritionally desirable, which is very useful to patients suffering from cardiological complaints. In India, maize is an important cereal crop possessing 4-5% oil content, while in USA, the available corn strains possess 18-20 percent oil content and is being cultivated extensively as an important source of edible oil of very good quality. Thus, efforts for high oil content would be desirable as maize has the potential as supplementary source of edible oil in the Indian situation but not at the expense of starch which is an important industrial by-product. The oil content in maize cultivars range from 3.6-6.8 percent (Sorte *et al.*, 2005) [44]

Effect of organic source of nutrients and their integrated use on performance of Maize

Dry matter production, grain and stover yield

The relevant information pertaining to the effect of inorganic and organic sources of nutrients either alone or in combination on dry matter production, grain and stover yields of maize is reviewed hereunder.

The major sources of organic manures often used in conjunction with the fertilizers are FYM, poultry manure and vermicompost. The rate of their application and the quantity of fertilizers combined with them is highly variable

Venkatesh *et al.* (2002) [49] reported that the application of 5 t ha^{-1} FYM and 2 t ha^{-1} lime in conjunction with 60 kg P_2O_5 increased the grain yield of maize in a acidic sandy loam soil deficient in available P and medium in available K. The application of 5 t ha^{-1} FYM vis –a- vis 120 kg N,75 kg P_2O_5 and 40 kg K_2O ha^{-1} in the clay soil of Bellary having low available N and P but high in K was reported to have increased the grain yield of maize substantially(Nalatwadmath *et al.*, 2003). The sandy loam soil with low organic carbon content and available N but medium in available P and K at New Delhi supplied with 10 t ha^{-1} FYM and Zn 5 kg ha^{-1} along with 120 kg N ha^{-1} was reported to enhance the dry matter production of the crop substantially (Karki *et al.*,2005). Malaiya *et al.* (2004) also recorded an increase in the dry matter production of maize due to the integrated supply of nutrients through 12 t FYM along with 60 kg N, 30 kg P and 30 kg K ha^{-1} at Chattishgarh. Jamwal (2005) reported the usefulness of combined application of 10 t FYM along with 40 kg N ha^{-1} in the sandy loam soil of Jammu and Kashmir having a low status in organic carbon, available N, medium in available P and low in available K. Confirming this trend, Verma *et al.*(2006) [50] reported that the application of 10 t FYM along with 150% recommended dose of N, P and K ha^{-1} increased the dry matter production of maize in the sandy clay loam soil of Udaipur in Rajasthan. It was rich in fertility with high level of available N, P and K. Summarizing the results of long term fertilizer experiments in alluvial soils of Ludhiana, red loam soils of Bangalore, medium black soils of Coimbatore and submontane soils of Palampur. Vats *et al.*(2001) concluded that the application of 10-15 t ha^{-1} of FYM along with recommended level of fertilizers was the best integrated nutrient management strategy to increase the dry matter production and yield of the crop. A more refined research strategy to substitute 50% N of the recommended dose of 50 kg N, 25 kg P and 12.5 kg K ha^{-1} with FYM was reported to have increased the dry matter production by Pathak *et al.* (2002) at Ranchi in Jharkand. Pathak *et al.* (2005) reported that the substitution of 25% N fertilizer with FYM increased the grain yield of maize.

The investigation of Madhavi *et al.* (1995) on the relative proportion of organic and inorganic source of nutrient supply confirmed that the application of 4.5 t poultry manure along with 120 kg N and 60 kg K_2O ha^{-1} enhanced the dry matter, grain and stover yield of maize in the sandy loam soil having medium organic carbon, low available N, P and medium available K at Hyderabad. The application of deep litter poultry waste and crop residue in 1:1 proportion @ 5 t ha^{-1} along with 150 kg N, 75 kg P_2O_5 and 50 kg K_2O ha^{-1} in the sandy loam soil having a moderate level of organic carbon low in available N and K but high in available P recorded higher dry matter production, grain and stover yield of maize at Bangalore (Mohamoud *et al.*, 2002) [24-25]. Relatively higher dose of poultry manure @ 10 t ha^{-1} and fertilizers @ 150 kg N, 75 kg P_2O_5 and 47.5 kg K_2O ha^{-1} applied in the clay loam soil of Arabhavi in Karnataka, having alkaline reaction, medium organic carbon, low available N but medium available P and K recorded maximum grain and stover yield (Chandrasekhara *et al.*, 2000). Thus the level of inorganic fertilizers and manure applied to soils of different texture varied with locations.

The application of vermicompost @ 1.5 t and 120 kg N ha^{-1} to a slightly alkaline clay soil in Gujarat was reported to be more beneficial than the fertilizer application to enhance the grain and stover yield (Meena *et al*., 2007) [23]. The application of 2.5 t ha^{-1} vermicompost along with 150 kg N, 75 kg P and 37.5 kg K ha^{-1} at Raichur (Kumar *et al.*, 2007) and the same dose of organic manure integrated with the fertilizers applied at 100 kg N, 50 kg P_2O_5 and 25 kg K_2O ha^{-1} in Dharwad (Lingaraju *et al.*, 2010) recorded maximum dry matter production, grain and stover yield of maize.

Sawarkar (2005) reported that the integration of 50 kg N, 25 kg P_2O_5, 15 kg K_2O and 25 kg zinc sulphate with phosphorus solubulising bacteria and Az*otobacte*r increased the grain yield of maize. Kumar and Dhar (2010) [17] reported that the integration of organic source of nutrients i.e., FYM + green manure with cowpea and application of *Azotobacter* with 60 kg N ha^{-1} through fertilizers increased dry matter, grain and stover yield of maize at New Delhi. The integration of nutrients by the application of 2.5 t Azolla compost with 50 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1} at Umiam in Meghalaya increased the grain yield of maize substantially (Das *et al.*, 2010). Auwal Tukur Wailare and Amit Kesarwani (2017) reported that highest plant height, leaf area, number of grains per cob, cob weight per plant, test weight and stover yield was observed with the with integrated nutrient management than recommended dose of inorganic fertilizer application.

Raman and Suganya (2018) evidently proved that 100% RDF + Press mud compost @ 5 t ha^{-1} in hybrid maize will be an appropriate Integrated nutrient management practice for achieving sustainable hybrid maize yield with due to care on soil health, fertility and productivity.

The review indicated the usefulness of applying different sources of organic manures along with the fertilizers to increase the dry matter, grain and stover yield.

Nutrient concentration and uptake

Jat and Balyan (2004) [12] recorded the usefulness of integrating Azospirillum with 150 kg N ha^{-1} which enhanced the uptake of nitrogen by maize in sandy laom soil.

Venkatesh *et al.* (2002) [49] observed that it was beneficial to integrate 5 t FYM, 2 t lime and 60 kg P_2O_5 ha^{-1} in P-deficient soil to enhance the uptake of this nutrient. The application of FYM along with fertilizers increased the uptake of nutrients in clay loam soil of Coimbatore (Santhy *et al.*, 1999) [39], sandy clay loam soil of Hyderabad (Chandra Pala *et al.*, 2010) [8], sandy loam soil of New Delhi (Kumar and Dhar, 2010) [17], loamy soil of Ranchi in Jharkhand (Pathak *et al.*, 2005) and clay soil of Kangara in Himachal Pradesh (Anil Kumar and Thakur., 2004) [1].

An improvement in the uptake of NPK by maize grown on the clay soil of Junagadh was also reported by the integrated supply of nutrients through 1.5 t ha^{-1} vermicompost and 120 kg N ha^{-1} through the fertilizer (Meena *et al.*, 2007) [23].

Quality Parameters

Protein content and yield

The scope to improve the protein content in the maize kernel is documented to a limited extent.

An increase in the percentage of protein in the kernels was recorded by application of *Azospirillum* along with 150 kg N ha^{-1} by Jat and Balyan (2004) [12]. Similarly, Meena *et al.* (2007) [23] ascertained the positive influence of organic manuring at 1.5 t vermicompost along with 120 kg N ha^{-1} to increase the protein percent.

Reddy *et al.* (2005) [36] recorded significant increase in protein content of maize by the conjunctive supply of nutrients through 10 t FYM along with recommended level of 150 kg N, 75 kg P_2O_5 and 40 kg K_2O ha^{-1}.

Reddy (2007) [34] reported that the substitution of 25% N fertilizer with vermicompost enhanced both the percent and production of protein in maize grain.

Oil content and oil yield

Work relating to the changes/ improvement in oil content and oil in maize as influenced by inorganic and organic sources of nutrients either alone or in combination is not significant.

Kumar (2005) [15] recorded significant improvement in the oil percent of maize kernel by substitution of 50% N fertilizer through FYM and the oil yield increased significantly by the substitution of 25% N fertilizer with poultry manure or vermicompost. Reddy (2007) [34] recorded significant improvement in the oil content by the substitution of 50% N fertilizer through FYM, and the oil yield increased significantly by the substitution of 25% N fertilizer with poultry manure or vermicompost

Conclusion

Several researches revealed that the application of recommended doses of fertilizers based on soil available status of nutrients significantly increased dry matter production, grain, stover yield, nutrient content their uptake, protein, oil content and yield of maize. Application of organic and biofertilizers along with inorganic fertilizers increased quality and production of maize and reduced 25-30 percent recommended fertilizer dose which benefits the soil environment.

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