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Efficacy of Nutrient Management on Carrot Productivity and Quality: A Review

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Abstract: Carrot is considered a highly nutritious root vegetable. For nutritional requirements like other plant species, carrot roots uptake minerals from the growing media and the growing media needs continuous input of minerals from external sources for continuous plant growth, optimal yield and desired quality. Increasing demand of 'organic' food and health concerns due to the application of chemical fertilizers has realized the need for application of organic manure to meet the increasing requirements of growing plants. This review briefly presents the scope of application of synthetic fertilizers as well as the natural manures for sustainable productivity and desired quality of carrot roots. An appropriate combination of synthetic fertilizers and natural manures is a possible way-forward to achieve reasonable yield and quality.

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1. Introduction

Carrot (*Daucus carota* L.) is a root crop of high nutritional and medicinal benefits. Central Asia is considered the origin of this crop and so it is considered as the center of its diversity(Simon, 2000).Carrot was spread both eastward and westward since its domestication and roots consumption began in 700 A.D. Turkey is assumed to be the secondary center of its diversity. The world carrot production is continuously increasing (FAO, 2015). Root color and flavor are the most important qualitative factors for selection of varieties (Kreutzmann et al., 2007).Continuous market research and parallel breeding programs are successfully delivering carrot in a range of colors and flavors meeting the requirements of the specific consumer groups (Surles et al., 2004). Root size and shape are also considered important selection parameters (Cardello, 1994). Besides these factors, the medicinal value of carrot has always been acknowledged(McNutt, 1994; Pieroni et al., 2007).

Plants fulfill their nutritional requirements by the uptake of minerals largely through soil (Cakmak, 2002). Soils of the cultivated areas have an ability to minimally sustain the plant growth with the nutrients held from previous crop rotation, but these nutrients are insufficient for higher production (Havlin, 2005).Nutrients applied to a growing crop are mainly consumed by the plants for the growth and development. Left over nutrients in the soil leach down (Grattan and Grieve, 1998)and become unavailable to the next crop. Resultantly, soils in the commercial crop growing areas do not hold sufficient quantity of nutrients as required for sustainable production and yield of plants. Application of chemical fertilizers is generally discouraged due to the increasing proportion of consumers of 'organic' food(Bourn and Prescott, 2002).Therefore, the nutrient management through organic sources of fertilizers to promote soil health and better plant nutrition has achieved a great deal of consideration on a global level. The organic sources improve physico-chemical characteristics and fertility of soil by different ways such as use of balanced amount of all nutrients and availability of the water for plant (Warman and Havard, 1997).

This manuscript presents a brief review on the efficacy of different combinations of fertilizers on productivity and quality of carrot fruit.

2. Chemical fertilizer requirement of carrot

Different types of fertilizer affect the yield and nutritional quality of carrot. Nitrogen (N) is not only an important element for the growth of carrot but it also affects the nutritional quality of the carrot roots (Kansal, 1981). The application of recommended rates of NPK enhanced the yield of carrot roots as compared to other organic and mineral fertilizers (Rani and Mallareddy, 2007). Application of N @ 75-150, Phosphorus @ 25-125 and K up to 175 kg ha^{-1} has been reported to increase the yield of carrot (Rubatzky et al., 1999).

The quality of the carrot is enhanced primarily by the effect of application of N because the N is important for the growth of the plant (Hochmuth, 2006). The application of N significantly enhanced the root yield of carrot (Hochmuth et al., 1999; Hailu et al., 2008). However, application of N @ 336 kg $ha^{-1}$are responsible for increasing the level of nitrate for baby food (Chessin and Hicks 1987; Cserni et al., 1989).

3. Increasing trend of organic food consumption

Proportion of organic food consumers is increasing (Seyfang, 2007) with the increasing awareness of health and food safety concerns (Dettmann and Dimitri, 2007).The foods produced by organic sources are safer and healthier for the human health. However, the consumers have to pay more price to get that food compared to the conventional food (Piyasiri and Ariyawardana, 2002; Zehnder et al., 2003).Different countries and, even within countries, different certifying agencies have varied regulations for governing the organic production of carrots (Nelson, 2004).

Food produced through the application of inorganic fertilizers safety issues as compared to the food obtained by the application of organic source. Inorganic source are used to obtain more yield as compared to the organic source of application but the safer food are obtained through the application of the organic application (Marcus, 2001). Consumers' produced organic food have good quality and safer for the humans (Shukla, 2001). The tagged baby organic foods are safer for the babies and also have less nutrient contents (Harris, 1997).

4. Application of manures for soil fertility

Considering the adverse effects on soil health and environment, besides the residual effect, excessive usage of inorganic fertilizers is not advisable. Several scientists are advocating the integrated nutrient management with natural and synthetic fertilizers to conserve the soil health and to get good quality produce (Rani and Mallareddy, 2007). The main sources of natural manures are; dung from cattle and farm animals, urine and litter, dropping of poultry and sheep and goat, kitchen waste from undesired parts of fruit and vegetables, residues/ waste of agricultural crops like sugarcane trash, wheat straw, waste from sugar and other similar industries and rice husk. All these natural manures have potential use for upgrading and maintaining organic matter in soil as well as to conserve itsbearing ability and material condition. The improved soil profile may also be helpful to increasing the synthetic fertilizer use efficiency of the soil (Khan, 2010).

The material and biochemical structure of soil is enhanced by the application of manures. The manures also supply nutrients, and increase soil fertility that ultimately leads to its' improved microbial activity (Zingore et al., 2007).Among all others manures, the poultry manures are more important because these provide more nutrients to the soil and its amendments in soil also increase the bearing level of the soil (Sims and Wolf, 1994).

Plant growth, soil bearing ability as well as material condition of soil are increased by use of poultry manures. N is nonetheless an important nutrient for the production of different crops and these are good sources of organic fertilizers. Organic sources of fertilizer are cheap compared to the inorganic sources of fertilizers and thus farmers can easily afford the cost of organic fertilizers (Rahman, 2004). John et al. (2004) stated that more crop yield is obtained by using both organic and inorganic source of fertilizers and it has less effect on the environment.

All the macro and micro nutrients are present in the poultry manure which is the organic source of fertilizer increase the fertility status of soil (Warman and Havard; Duncan, 2005). However, the application of poultry manures more than @ 18 t ha^{-1}, has negative impact on the crop (Edwards and Daniel, 1992). Similarly, application of poultry manure @ 180 t ha^{-1} in sandy loam soil enhanced the level of nitrate at the depth of 300 cm (Liebhardt et al., 1979)and in silt loam soils its level is increased at 120 cm (Adams et al., 1994).

Application of poultry manure significantly improved soil fertility as well as the physical properties along with the yield of the crops (Mufwanzala and Dikinya, 2010). It also increased

the growth and yield of the different vegetables and pastures (Edwards and Daniel, 1992). Management and maintenance of soil fertility level is critical to sustainable food production (Prasad and Power, 1997). N and P are available from poultry manures as compared to all other sources of organic manures. Average nutrient contents in poultry manure are N-3.03%, P-2.63% and K-1.4% (Guled et al., 2003).

Poultry manure was found the most nutritious and effective to increase plant yield compared with the household and kitchen waste, market waste, and farm yard manure (Adediran et al., 2003). Also the poultry manure improved the soil profile and enhanced the macro micronutrient contents in the soil. Improvement in soil profile in terms of pH and nutrients including N, P, K, Ca, and Mg and the uptake of nutrients is also reported to be highly associated with the application of poultry manure (Akande and Adediran, 2004). Additionally, the application of poultry manure in the cultivated land has been reported to recycle the nutrients available in the soil and hence, it reduces the cost of application of fertilizers and therefore, the cost of crop production. Furthermore, the poultry manure can complement the action of other organic manures when applied before crop production in succeeding season (Eghball et al., 2004) in view of the proven fact that poultry and other animal manures not only increase the soil inorganic pool (Abbasi et al., 2207) but also these do increase the seasonal soil mineralization available to the crops (Ma et al., 1999). In this context, the application of organic manure is reported to further enhance the physical and bio-chemical properties of soil when incorporated with rice and wheat straw. The nutrient value of compost and natural manures depends largely upon the nature and formulation of animal feed, type and stage of harvest of fodder, and methods of preparation and storage of compost and the natural manures (Maskey and Bhattarai, 1984).

Traditionally, any animal manure, for example the poultry manure, is not used in soil preparation for carrots even though it was tested successfully in some other crops. The carrot producers had a threat that application of poultry manure may cause root forking. However, recent research has reported that application of poultry manure as soil dressing before plantation of carrot roots increased crop yield and helped advance the crop maturity and it did not significantly increase the root forming (Phillips et al.,2002). In other crops, for example in eggplant Aliyu (2000) reported that the use of organic manure for farm yard plus the poultry manure applied at 5 t ha^{-1} increased the yield per plant.

5. Recommendations for improved productivity and quality

It is not concluded if the organic or the chemical fertilizers affect the nutritional value or quality of the fruit or vegetables (Bourn and Prescott, 2002; Brandt and Molgaard, 2001). The balanced amount of organic and mineral fertilizers have intense importance because of the improved fertility status of soil, its' productivity, sweetness as well as improved α and β contents. The negative impact of these fertilizers on environment and the material condition of soil is lower (Rani and Mallareddy, 2007). However, the main important issue is that the organic fertilizers are slowly available to the crops as compared to the inorganic fertilizers (Hailu et al., 2008).The precise recommendations for inorganic fertilizers are difficult because the nature of the soil varies from one place to the other and hence, the specific recommendations need to be site specific (Rubatzky, 1999). Nitrogen contents increase with increase in Nitrogenous fertilizer. Vitamin C and Nitrate N have antagonistic interaction and decrease with increasing Nitrate.

The model of application for the combination of organic and chemical fertilizers has shown remarkable effects on yield and quality. For example, 50% of the recommended dose of fertilizer and farm yard manure (~12.5 t ha^{-1}) applied with reduced level of recommended dose of fertilizer (50%) helps in higher vegetative growth and yield of tomato (Rafi et al., 2002). Similarly, application of NPK (80:60:50 kg/ha) + farm yard manure (20 $t.ha^{-1}$) helped in obtaining higher plant height, number of leaves, internodal length and number of nodes in okra (Naidu, 1999).

Application of farm yard manure (12.5 t ha^{-1}) + wet able sulfur (20 t ha^{-1}) + urea (60 t ha^{-1}) resulted in higher plant height, number of leaves and herbage yield over other treatment in sweet basil (Sundharaiya, 2003). In potato crop, continuous application of farm yard manure produced higher yield than the combined application of P and K as inorganic fertilizers (Sharma et al., 1979). Sharma et al. (1980) observed significant and positive effect of farm yard manure on yield as well as indicated that translocation was improved due to application of farm yard manure in summer crop. Sahota and Govindkrishnan (1984) reported the production of medium sized potato tubers when farm yard manure

(20 t ha^{-1}) was applied with recommended dose of fertilizers.

However, application of farm yard manure in potato crop at 15 and 30 t ha^{-1} increased the tuber yield by 39 and 40%. They further reported that higher yield was due to the improvement in tuber size. Similarly, higher yield of fresh rhizomes were recorded in turmeric through the application of organic manure (25 t ha^{-1}) (Mandal and Mazumdar, 1986). Application of organic manure (25 t ha^{-1}) + NPK recorded significantly higher yield compared to farm yard manure alone and NPK in cabbage, onion and carrot (Balashanmugam et al., 1989). Hayworth et al. (1966) demonstrated the beneficial effects of farm yard manure on yield of carrot roots. However, organic manures did not generally increase the yield of carrot (Luzzati et al., 1975). In a study on tomato production, different sources of N were tested and it was found that sources of N other than compost yielded higher production. This was probably due to the C:N ration in compost which did not release N for plant use (Goh and Vityakon, 1986).

Low N availability can also lead to higher ascorbic acid accumulation lower the carotenoid concentration (Kaack et al., 2001).Improved tomato fruit quality as determined by total soluble solids applied by high concentrations of NH^+ and low NO_3^- was reported by Gao et al.(1996). According to the 'C:N balance theory', when N is available to plants in abundance, the plants would synthesize high N contents containing compounds. These may include proteins for growth and alkaloids. However, when N supply to the plant is limited, more the carbon-containing compounds are produced. These may include starch and cellulose. Also the phenolics as well as terpenoids are reported (Haukioja et al., 1998). Therefore, secondary metabolites produced by the plants could be different in relation to different forms of fertilizers (Brandt et al., 2001).

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