Review

Macroelements nutrition (NPK) of medicinal plants: A review

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The use of medicinal plants to treat diseases since ancient times has been applied. Nowadays, the number of the plants used for medicinal purpose is about 35,000 species. In this study, the effect of macro elements (nitrogen, phosphorus and potassium) on the properties of medicinal plants was reviewed. Investigations carried out showed that with adequate supply of N, P and K utilization by various spice crops are enhanced. Macro elements caused increase the number of traits such as plant height, leaf area, yield seed, and oil content. Some of traits of medicinal plants such as basil, turmeric, black pepper, cardamom, fennel, fenugreek, and Aloe vera with used potassium were changed.

Key words: NPK fertilizer, medicinal plants, soil, nutrition.

INTRODUCTION

Plants have been used in treating human diseases for thousands of years. Some 60,000 years ago, it appears that Neanderthal man valued herbs as medicinal agents, this conclusion is based on a grave in Iran in which pollen grains of eight medicinal plants were found (Solecki and Shanidar, 1975). Plant materials are used throughout developed and developing countries as home remedies, over-the-counter drug products and raw materials for the pharmaceutical industry, and represent a substantial proportion of the global drug market (Ross, 2005). The interest in Nature as a source of potential chemotherapeutic agents continues. Natural products and their derivatives represent more than 50% of all the drugs in clinical use in the world. Higher plants contribute no less than 25% of the total (Ameenah, 2006). There are some 240,000 species of higher plants (medicinal and non medicinal) and not all of those species will have the same mineral needs, at the same scale. Some will require a specific element in much higher concentration than others, and others will be able to tolerate a much higher concentration of an essential element that would, be toxic, to a different species. Such variability is inherent in biology, and for this reason most generalities, such as the definition of an essential nutrient, need to have some wiggle room in interpretation. Nutrient deficiencies in plants are often made most evident by plant physiological responses (Clarkson and Hanson, 1980). Nutrient deficiency symptoms tend to occur in three major patterns: localized to the younger tissues, localized to the more mature tissues, or widely distributed across the plant. In each case, the distribution of the symptoms can help a person determine the nature of the deficiency experienced by the plant or, if the deficient nutrient is already known, make an inference about the role the nutrient plays in the plant body (Wiedenhoeft, 2006). Fourteen mineral nutrients are classified as either macronutrients or micronutrients based on their plant requirements. There are six macronutrients: Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). The macronutrients, N, P, and K, are often classified as ‘primary’ macronutrients, because deficiencies of N, P and K are more common than the ‘secondary’ macronutrients, Ca, Mg, and S. The micronutrients include boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn). Most of the macronutrients represent 0.1 to 5%, or 100 to 5000 parts per million (ppm), of dry plant tissue, whereas the micronutrients generally comprise less than 0.025%, or 250 ppm, of dry plant tissue (Wiedenhoeft, 2006).

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PHOSPHORUS (P)

Phosphorus is frequently a limiting nutrient, particularly in tropical regions, where the soil chemistry differs from temperate soils, or in highly weathered soils, where phosphorus has long since leached away. Phosphorus is one of the three main elements in commercial lawn fertilizers, though there is mounting evidence that many lawns and green areas already have ample phosphorus, and thus it is being phased out of some commercial fertilizers. The ultimate source of virtually all terrestrial phosphorus is from the weathering of minerals and soils in the Earth’s crust. Phosphorus is generally available as phosphate, an anion that is not bindable by the cation exchange complex and thus can be easily leached from the soil by rain or runoff (Wiedenhoeft, 2006).

Role of phosphorus in plant growth

Phosphorus has many important functions in plants and medicinal plants, the primary one being the storage and transfer of energy through the plant. Adenosine diphosphate (ADP) and adenosine triphosphate (ATP) are high-energy phosphate compounds that control most processes in plants including photosynthesis, respiration, protein and nucleic acid synthesis, and nutrient transport through the plant’s cells (Sharpley et al., 1996).

Role of phosphorus in medicinal plants

Plant height

Boroomand et al. (2011a) found that application of 100 kg P₂O₅ ha⁻¹ increased leaf number and leaf length in Aloe Vera. Boroomand et al. (2011b) reported significantly higher plant height of Basil at 150 kg P₂O₅ ha⁻¹ (78.96 cm in 2009) which was superior over all other P levels. One of the earliest and most pronounced responses to phosphorus deficiency is reduction in shoot growth, specifically reduction in leaf number and leaf size (Lynch et al., 1991). Shoot development requires the production of leaves by shoot apical meristem and their subsequent expansion. Decreased number of leaves with phosphorus deficiency implies changes in leaf initiation and activity of shoot apical meristem. Plant height of Phaseolus trilobus was increased due to increased phosphorus fertilization at 80 kg P₂O₅ ha⁻¹ (Kumar et al., 2002).

Anilkumar et al. (2001) reported significantly higher plant height of mustard at 37.35 kg P₂O₅ ha⁻¹ (209.4 and 208.0 cm during 1998 and 1999, respectively) which was superior over all other P levels. Panwar and Singh (2003) recorded significantly higher plant height of groundnut at 60 kg P₂O₅ ha⁻¹ (49.80 cm) over control (46.55 cm). Field investigation carried out by Pareek et al. (2002), to study the effect of P₂O₅ levels on growth of Panchpatra (Ipomoea pestigrides), showed that maximum plant height per plant was obtained by application of 25 kg P₂O₅ per ha. But increased levels of P₂O₅ over 25 kg P₂O₅ decreased this parameter. Harendra and Yadav (2007) reported that plant height of mustard increased significantly with each increment in the dose of phosphorus up to 13.1 kg P₂O₅ ha⁻¹ (165.7 cm). However, the differences in plant height due to further increase in the dose of phosphorus to 39.3 kg P₂O₅ ha⁻¹ were not significant.

Number of branches in a plant

Pareek et al. (2002) reported significantly higher number of branches of Panchpatra at 25 kg P₂O₅ ha⁻¹. Harendra and Yadav (2007), reported significant increase in the number of primary branches of mustard with an increase in the phosphorus levels from 0 to 13.1 kg P₂O₅ ha⁻¹ which was 5.3 and 6.2 plant⁻¹, respectively. But, there was no significant increase in the number of primary branches with further increase in the P level at 39.3 kg P₂O₅ ha⁻¹ (6.5 plant⁻¹).

Saraf et al. (2002), studied the effect of two levels of P₂O₅ (25 and 50 kg ha⁻¹) on the yield of Danti (Baliospernum montanum) crop. The effect of phosphorus was significant and the highest plant height, number of leaves per plant, branches per plant and plant spread were observed with the application of 50 kg P₂O₅ per ha as compared to 25 kg P₂O₅ per ha⁻¹.

Leaf area

Plants ultimately depend on green leaf area for dry matter accumulation as the leaves intercept solar radiation and produce photosynthates through photosynthesis. The production, expansion and survival of green leaves are the important determinants of crop productivity. The primary symptoms of nutrient deficiency are reduction in leaf expansion. Boroomand et al. (2011b), in a study on Basil reported that increased level of P₂O₅ from 50 to 150 kgh increased leaf area from 18.13 to 23.25, respectively. In Aloe Vera application, 150 kgh P₂O₅ cause increased leaf area (Boroomand et al., 2011a).

Seed yield

Though the magnitude of the responses of oilseed crops to applied phosphorus is less than that of nitrogen, results of several experiments do indicate that in situation where soil phosphorus level is low, significant responses can be obtained. Kumar et al. (1987), studied the responses of fenugreek to phosphorus application 50 kgh caused increased seed yield. Application of phosphorus at 0, 17 and 34 kg ha⁻¹ recorded seed yield of 963, 1178...
and 1185 kg ha\(^{-1}\) in the first site and 1038, 1435 and 1494 kg ha\(^{-1}\) in the second site. Esskaf and Aljaro (1982) recorded no significant effect on the growth and yield of Garlic with the application of 41.11 kg P ha\(^{-1}\) during bulbing and root growth. Minard (1978), on the other hand reported 114.75 kg P ha\(^{-1}\) as optimum for increased final bulb yield among other parameters. Bandopadhyay and Samul (1999) studied the effect of varied levels of phosphorus on seed yield of groundnut and concluded that there was significant response to phosphorus up to 100 kg ha\(^{-1}\) (1625.20 kg ha\(^{-1}\)). Bhari et al. (2000) recorded significantly higher seed yield of mustard at 45 kg P2O5 ha\(^{-1}\) (2.36 q ha\(^{-1}\)) which was superior over all other P levels including control. Farahani and Khalvati (2011) reported significantly higher seed yield of coriander at 70 kg ha\(^{-1}\) P2O5 which was superior over all other P levels.

**Oil content**

Application of 100 kg P2O5 h to Basil resulted in significantly higher oil content (2.40%) which was superior over all other P levels (Boroomand et al., 2011b). Harendra and Yadav (2007) reported significant increase in the oil content of mustard with increase in P level from 0 to 39.3 kg P2O5 ha\(^{-1}\).30 per cent of oil content was recorded at 39.3 kg P2O5 ha\(^{-1}\) which was significant over all other levels including control. Lewis et al. (1987) examined the response of oilseed rape to phosphorus fertilization at 21 sites and significant increase in oil content to the tune of 0.7 per cent was recorded in only one site. Boroomand et al. (2011a) recorded significantly higher gel content of Aloe Vera at 150 kg P2O5 which was superior over all other P levels including control. Response of various crops to phosphorus application indicated that yield and growth attributing parameters increased with increase in levels of P2O5 and the response varied from 25 to 80 kg P2O5 per ha\(^{-1}\).

**NITROGEN (N)**

The largest natural source of nitrogen is the Earth’s atmosphere, which is roughly 78% gaseous nitrogen, an inert and essentially biologically unavailable form of the element. Its biological unavailability is because the two nitrogen atoms form an extremely stable bond, which is not easily broken. Apart from human industrial processes that fix nitrogen gas to solid or liquid forms, the primary means of nitrogen fixation are through the high temperature and energy of lightning strikes and biological nitrogen fixation by bacteria. These processes produce nitrogen in three main forms, each of which are available to plants: nitrate, nitrite, and ammonium (Wiedenhoeft, 2006).

**Role of nitrogen in plant growth**

Within the plant, nitrogen serves in the same ways as it does in other organisms as a component of amino acids and nucleic acids. Nitrogen also plays a critical role in the structure of chlorophyll, the primary light harvesting compound of photosynthesis. This, along with its structural role in amino acids, explains why plants require large amounts of nitrogen, and thus why it is often the limiting nutrient for plant growth.

**Role of nitrogen in medicinal plants**

**Plant height**

Moradkhani et al. (2010) reported in *Melissa officinalis* L plant height (61.63 cm) was obtained under application of 90 kg N ha\(^{-1}\). Suresh (1980) revealed that, application of nitrogen at 100 kg per ha was optimum in increasing stem diameter, while nitrogen at 150 kg per ha was found to be optimum in increasing plant height of *Catharanthus roseus* (79.69 cm).

Garnayak et al. (2000) studied the effect of varied levels of nitrogen on plant height of mustard and reported significant increase in the plant height with an increase in the level of nitrogen application from 0 to 120 kg N ha\(^{-1}\). The highest was recorded in the treatment supplied with 120 kg N ha\(^{-1}\) which was 200 cm. Okut and Yidirmi (2005) concluded that application of 90 kg N ha\(^{-1}\) in coriander resulted in significantly higher plant height (37.10 during 1998/1999). Attoe and Osodeke (2009) reported significantly higher plant height of Ginger (*Zingiber officinale roscoe*) at 200 kg N ha\(^{-1}\) (54.50 cm) than other level of nitrogen.

**Number of branches in a plant**

Number of branches plant, the parameter related to yield and dry matter production of crops, is positively affected by nitrogen. Mekawey et al. (2010) reported that application of 150 kg N ha\(^{-1}\) in coriander recorded significantly higher number of secondary branches (8.37 plant\(^{-1}\)) over control (6.05 plant\(^{-1}\)) and was on par with 100 kg N ha\(^{-1}\) (6.57 plant\(^{-1}\)) and 200 kg N ha\(^{-1}\) (6.91 plant\(^{-1}\)). Amit and Sundeen (2007) reported significantly higher number of primary branches of mustard at 140 kg N ha\(^{-1}\) (7.9 plant\(^{-1}\)) which was superior over all other N levels but was on par with 120 kg N ha\(^{-1}\) (7.9 plant\(^{-1}\)). Attoe and Osodeke (2009) studied the effect of nitrogen level on number branch in ginger. They understood that treatment 200 kg of nitrogen produces greatest number of branches.

**Seed yield**

Sadanandan and Shashidharan (1979) studied the effect
of six levels of N on yield of ginger with (0, 25, 50, 75, 100 and 125 kg ha\(^{-1}\)). The effect of nitrogen was significant and the highest yield (8595 kg ha\(^{-1}\)) was obtained from the treatment receiving 50 kg N per ha and the treatment with zero N recorded the lowest yield (2995 kg ha\(^{-1}\)). Lalitha and Gopala (2004) reported significantly higher seed yield of groundnut at 80 kg N ha\(^{-1}\) (2532 kg ha\(^{-1}\)) over all other N levels, but was significantly lower at 120 kg N ha\(^{-1}\) (2383 kg ha\(^{-1}\)). Buwalda (1986) studied the effect of nitrogen level between 0 and 240 kg ha\(^{-1}\) on yield in late California cultivar Garlic. He reported that the rate of 120 kg ha\(^{-1}\) of N had the best relationship between yield and quality. To obtain high yield, it is necessary that continuous nitrogen assimilation be maintained until the maturation stage. According to Sarma (1985), significantly higher seed yield of castor was recorded at 80 kg N ha\(^{-1}\) with 90 kg nitrogen as basal dose and 40 kg as top dressing (1426 kg ha\(^{-1}\)) which was superior over all other N levels including control.

Role of potassium in plant growth

Potassium is the primary osmolyte and ion involved in plant cell membrane dynamics, including the regulation of stomata and the maintenance of turgor and osmotic equilibrium. It also plays important roles in the activation and regulation of enzyme activity (Wiedenhoeft, 2006).

Role of potassium in medicinal plants

Plant height

Borromand et al. (2011a) studied the effect of varied levels of potassium on leaf length of Aloe Vera and reported significant increase in the leaf length with an increase in the level of potassium application from 0 to 150 kg K ha\(^{-1}\). Balashanmugam and Subramanian (1991) recorded maximum plant height (152.80 cm), number of leaves (15.80), and number of suckers per clump (11.32) in turmeric with the application of potassium at 90 kg per ha\(^{-1}\).

Yield

Muralidharan (1973) and Muralidharan et al. (1976) reported a slight increase in the yield of fresh ginger rhizome when potassium was raised from 100 to 150 kg per ha\(^{-1}\). Further increase in K\(_2\)O levels showed a decline in the yield. However, the differences were not significant. A field experiment conducted with two levels of potassium at 25 and 50 kg K\(_2\)O per ha\(^{-1}\) revealed that the plant characters studied did not show any significant differences due to the application of K\(_2\)O to Danti crop (Saraf et al., 2002). Ashokan et al. (1984) reported that application of 60 kg K\(_2\)O per ha\(^{-1}\) produced maximum marketable tuber yield of sweet potato (13.8 t ha\(^{-1}\)), dry matter content in vine (11.9 %) and tuber (30.7 %) as compared to 30 kg K\(_2\)O per ha\(^{-1}\).

Some medicinal plant responses to potassium

Cardamom (Elettaria cardamomum)

Vasantha and Mohanakumaran (1989) reported that for cardamom, potassium content of leaves and pseudo stem was maximum at the flower bud growth and peak flowering stages respectively, and thereafter K concentration of rhizome, roots and panicles showed peak values at capsule maturity stage. Sadanandan et al. (1993) reported that 150 kg K\(_2\)O ha\(^{-1}\) year is optimum, whereas Korikanthimath (1994) reported that 240 kg K2O ha\(^{-1}\) year is needed under high-density trench system of planting. Cardamom being a perennial crop and steady absorption and utilization of K take place throughout its life cycle and it is a heavy feeder of K (Kulkarni et al., 1971).
Table 1. Recommendation for use fertilizer in medicinal plants on soil analysis.

<table>
<thead>
<tr>
<th>Level of available (NPK) in soil</th>
<th>Quantity</th>
<th>Probability response to NPK fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N (%)</td>
<td>&lt; 0.2 (% O.C*&lt;1)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>0.2-0.5 (%O.C=1-2)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>&gt;0.5 (%O.C&gt;2)</td>
<td>Low</td>
</tr>
<tr>
<td>P&lt;sub&gt;av&lt;/sub&gt;(mgkg&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>&lt;10</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>10-15</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>&gt;15</td>
<td>Low</td>
</tr>
<tr>
<td>K&lt;sub&gt;av&lt;/sub&gt;(mgkg&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>&lt;50</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td>50-100</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>100-200</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>&gt;200</td>
<td>Low</td>
</tr>
</tbody>
</table>


Ginger (Zingiber officinale)

It was reported that, for optimum productivity, NPK 75, 50, 50 kg together with 25 tonnes green leaf and 20 tonnes farmyard manure (FYM) is required (Sadanandan et al., 1988). Sadanandan and Rohini (1986) reported that application of two tonnes neem cake together with NPK 75, 50, 50 kg has increased ginger yield by 32.8% and restricted rhizome rot disease incidence to 4.7% compared to 14.5% in FYM treated plots.

Pepper (Piper nigrum L)

Integrated nutrient and disease management studies in a mixed cropping system with black pepper conducted in the farmer's fields for four years showed that application of FYM, Neem cake and bone meal 5, 1 and half kg vine year together with NPK fertilizer at a subdued level of 100, 40, 140 g vine year increased soil available K status by 45%, leaf K status by 13% and pepper yield by 172% (Sadanandan et al., 1993b). For pepper, Pillai et al. (1987) reported that 200 g K<sub>2</sub>O vine as optimum whereas Sadanandan (2000) reported up to 270 g K<sub>2</sub>O vine as optimum dose by studying response function. Waard and De (1969) reported critical level of K up to 2% in pepper leaf. For bush pepper growing in pots, application of NPK 1, 0.5, 2g pot (10 kg soil) was optimum. Further K<sub>2</sub>SO<sub>4</sub> was a better source than KNO<sub>3</sub>, KCl and wood ash for bush pepper (Sadanandan and Hamza, unpublished). Leaf nutrient norms for black pepper using diagnostic recommendation integration system (DRIS) Sadanandan et al. (1996) reported that in pepper leaves potassium concentration of 0.33% is deficient, 0.33 to 17% as low, 1.18 to 2.84% as optimum, 2.85 to 3.68% as high and more than 3.68% as excessive level.

Turmeric (Curcuma longa)

Rethinavel (1983) reported significant increase in plant height, tiller production number of leaves, number of mother, primary and secondary rhizomes and ultimately yield of turmeric due to potassium application. Sadanandan and Hamza (1996b, 1998) reported that NPK 60, 50, 120 kg ha<sup>-1</sup> with micronutrients were optimum for varieties Suvarna, Suguna and Alleppey, whereas NPK 50, 40, 100 kg ha<sup>-1</sup> with micronutrients was optimum for Sudarshana.

Seed spices: Coriander (Coriandrum sativum), Cumin (Cuminum cymimum), Fennel (Foeniculum vulgare) and Fenugreek (Trigonella foenum graecum). Fertilizer response studies for seed spices were conducted by several workers. Fageria et al. (1972) reported good response to K<sub>2</sub>O up to 80 kg ha<sup>-1</sup> for cumin. Pillai and Boominathan (1975) reported response of coriander to potassium up to 20 kg ha<sup>-1</sup>. Afridi et al. (1983) reported response of potash to fennel up to 90 kg ha<sup>-1</sup>. Studies conducted by “all India coordinated work project on Spices” at their centers in major seed spices growing belts of Rajasthan and Gujarat showed that for coriander 20 kg K ha<sup>-1</sup> was optimum (Rethinam and Sadanandan, 1994). The requirement of K for cumin is 30 to 45 kg depending upon K status of the soil. For a crop of fenugreek 50 kg K2O ha<sup>-1</sup> was adequate (Sadanandan and Hamza, 1998). Our general recommendations for the use of fertilizer N, P and K on the medicinal plants are found in Table1.

CONCLUSION

Depending on crop, the response to N, P and K
application varied. Medicinal crops like C. roseus showed response to as low as 20 kg K₂O per hectare and on the other hand, ginger yield could be raised by applying 150 kg K₂O per ha. Studies indicates that N, P and K nutrients applied in some definite combinations caused increase in yields rather than supplying either of the major nutrients alone.

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REFERENCES


