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DISCUSSION

Environmental conditions regulate growth and development of plants considerably. Proper management of nutritional inputs, like adequate amount and balanced ratio of applied nutrients and their time of application also influence growth and development. This applies particularly to crop plants due to economic considerations.

It is common knowledge that absorption of nutrients continues throughout the life of plants. However, their nutrient requirements may increase with the development of sink. When plants grow old, the absorption process may become slow. It may be due to the weakening of the root system or unavailability of nutrients resulting from leaching, fixation and decomposition leading to a lowering of the nutrient status of plants, particularly at crucial stages of their growth. Under such conditions, the ready availability of adequate quantities of nutrients, via supplemental top-dressing/foliar spray and/or their efficient absorption and utilization with the help of some stimulant, is highly desirable to ensure the full realization of their genetic potential. Understandably, this has proved a highly successful technique for profitable cultivation of a number of crop plants.

Knowledge of the physiological basis of the performance of a plant is helpful to assess its relationship with the environmental conditions, including nutritional inputs. Thus, on the basis of the observation of relevant growth parameters, physiological markers and yield-attributing characteristics, studied at various stages, one can determine the role played by the nutritional inputs as well as stimulants, if applied.

For the present study, two important medicinal plants Plantago ovata Forsk. and Trigonella foenum-graecum L. were selected. The main aim was to test the feasibility of the realization of the yield potential of these crops through
adequate, balanced and efficient utilization of nutritional inputs and an often-tested and popular phytohormone. The results of two pot and two field experiments each on the two crops grown under various regimes of nutrients and of gibberellic acid application through foliar spray are discussed in the following pages, in the light of the knowledge available on the subject and the work done, particularly in India, by other researchers.

The perusal of the data of Experiments 1 (Tables 6–14), 2 (Tables 15–23), 5 (Tables 42–60) and 6 (Tables 61–79) on Plantago ovata Forsk. and of Experiments 3 (Tables 24–32), 4 (Tables 33–41), 7 (Tables 80–99) and 8 (Tables 100–119) on Trigonella foenum-graecum L. reveals several noteworthy responses that happened to be common in the two crops tested and are further discussed below.

5.1 Growth parameters

Increase over the no-nutrient control in root length, secondary root number, nodule number, plant height, culm number/branch number, leaf number and leaf area, at 60, 90 and 120 DAS, resulted from the application of nitrogen and/or phosphorus to the soil in Plantago ovata Forsk. in Experiments 1, 2, 5 and 6 (Tables 6, 8, 9, 15, 17, 18, 42, 43, 46–49, 61, 62, 65–68) and in Trigonella foenum-graecum L. in Experiments 3, 4, 7 and 8 (Tables 24, 26, 27, 33, 35, 36, 80–82, 85–88, 100–102, 105–108). This is on expected lines and corroborates the findings for Plantago ovata Forsk. of Joshi et al. (1968), Randhawa et al. (1978; 1982), Samra and Gill (1986), Ramesh et al. (1989), Singh and Chouhan (1994) and Chouhan and Joshi (2000) and for Trigonella foenum-graecum L. of Pareek and Gupta (1981), Anand and Sharma (1987), Patel et al. (1991), Mandal and Maiti (1992), Bhati (1993), Banafar et al. (1995), Sreeramulu et al. (1996), Dayanand et al. (1998), Gogoi et al. (1998), Halesh et al. (1998), Kumawat et al. (1998), Chaudhary (1999a, b) and Sheoran et al. (1999).
Plants absorb mineral nutrients from the soil, which is their primary source, through their root system. Thus, raising of crop plants year after year in the same field results in deficiency of the more heavily-demanded nutrients, like nitrogen, phosphorus and potassium, if these are not added adequately and regularly before each sowing (Miller and Donahue, 1990). The observed enhancing effect of the application of these nutrients can be explained on the basis of their metabolic roles in plants as elaborated earlier (pages 8, 9). Thus, on the basis of the roles played by these nutrients, it can easily be recognized that their direct or indirect involvement in cell division, cell enlargement and tissue and organ formation would be expected to result in improvement in these structures. This, in turn, would explain the observed increase in root length (Tables 6, 15, 42, 61 for Plantago ovata Forsk. and 24, 33, 80, 100 for Trigonella foenum-graecum L.), secondary root number (Tables 6, 15, 43, 62 for Plantago ovata Forsk. and 24, 33, 81, 101 for Trigonella foenum-graecum L.), nodule number (Tables 24, 33, 82, 102 for Trigonella foenum-graecum L.), plant height (Tables 8, 17, 46, 65 for Plantago ovata Forsk. and 26, 35, 85, 105 for Trigonella foenum-graecum L.), culm number (Tables 8, 17, 47, 66 for Plantago ovata Forsk.), branch number (Tables 26, 35, 86, 106 for Trigonella foenum-graecum L.), leaf number (Tables 9, 18, 48, 67 for Plantago ovata Forsk. and 27, 36, 87, 107 for Trigonella foenum-graecum L.) and leaf area (Tables 9, 18, 49, 68 for Plantago ovata Forsk. and 27, 36, 88, 108 for Trigonella foenum-graecum L.).

The increased root length and secondary root number in the two crops would enhance their nutrient absorption capacity. Interestingly, it would also provide larger area for nodule development in Trigonella foenum-graecum L. The enhanced nodule number would thus fix additional molecular nitrogen leading to improvement in nitrogen metabolism in Trigonella foenum-graecum L. Improved plant height, culm number/branch number and leaf area would
provide better orientation of leaves which, in turn, would help harvest larger quantities of solar energy by the plants.

The ameliorating effect of foliar application of gibberellic acid on the above stated growth parameters of Plantago ovata Forsk. in Experiments 5 (Tables 42, 43, 46-49) and 6 (Tables 61, 62, 65-68) and of Trigonella foenum-graecum L. in Experiments 7 (Tables 80-82, 85-88) and 8 (Tables 100-102, 105-108) corroborates the findings of Dijkstra and Kuiper (1989) on Plantago major L. and Desai and Pathak (1965), Anand and Sharma (1988) and Alhadi et al. (1999) on Trigonella foenum-graecum L.


Possibly, these roles of gibberellic acid would have contributed towards enhanced root length (Tables 42, 61 for Plantago ovata Forsk. and 80, 100 for Trigonella foenum-graecum L.), secondary root number (Tables 43, 62 for Plantago ovata Forsk. and 81, 101 for Trigonella foenum-graecum L.), nodule number (Tables 82, 102 for Trigonella foenum-graecum L.), plant height (Tables 46, 65 for Plantago ovata Forsk. and 85, 105 for Trigonella foenum-graecum L.), culm number/branch number (Tables 47, 66 for Plantago ovata Forsk. and 86, 106 for Trigonella foenum-graecum L.), leaf number (Tables 48, 67 for Plantago ovata Forsk. and 87, 107 for Trigonella foenum-graecum L.)
and leaf area (Tables 49, 68 for *Plantago ovata* Forsk. and 88, 108 for *Trigonella foenum-graecum* L.).

The noteworthy stimulatory interaction effect of nitrogen and phosphorus applied together and gibberellic acid (NP × GA) on the growth parameters of *Plantago ovata* Forsk. in Experiments 5 (Tables 42, 43, 46-49) and 6 (Tables 61, 62, 65-68) and of phosphorus only and gibberellic acid (P × GA) in the case of *Trigonella foenum-graecum* L. in Experiments 7 (Tables 80-82, 85-88) and 8 (Tables 100-102, 105-108) corresponds with the finding of Khan *et al.* (1997), Khan and Samiullah (1997) and Santos *et al.* (1998) working on other crops.

The beneficial interaction effect of nutrient/s with gibberellic acid resulted in enhanced root length (Tables 42, 61 for *Plantago ovata* Forsk. and 80, 100 for *Trigonella foenum-graecum* L.), secondary root number (Tables 43, 62 for *Plantago ovata* Forsk. and 81, 101 for *Trigonella foenum-graecum* L.), nodule number (Tables 82, 102 for *Trigonella foenum-graecum* L.), plant height (Tables 46, 65 for *Plantago ovata* Forsk. and 85, 105 for *Trigonella foenum-graecum* L.), culm number/branch number (Tables 47, 66 for *Plantago ovata* Forsk. and 86, 106 for *Trigonella foenum-graecum* L.), leaf number (Tables 48, 67 for *Plantago ovata* Forsk. and 87, 107 for *Trigonella foenum-graecum* L.) and leaf area (Tables 49, 68 for *Plantago ovata* Forsk. and 88, 108 for *Trigonella foenum-graecum* L.).

As would be expected, increase in root length, secondary root number (Tables 6, 15, 42, 43, 61, 62 for *Plantago ovata* Forsk.) and also nodule number (Tables 24, 33, 80–82, 100–102 for *Trigonella foenum-graecum* L.) contributed significantly towards enhancing the capacity of the treated plants for root biomass production. This is reflected in the observed increase in the fresh and dry weight of root (Tables 7, 16, 44, 45, 63, 64 for *Plantago ovata* Forsk. and 25, 34, 83, 84, 103, 104 for *Trigonella foenum-graecum* L.). Also enhancement in plant height, culm number/branch number, leaf number and
leaf area (Tables 8, 9, 17, 18, 46–49, 65–68 for *Plantago ovata* Forsk. and 26, 27, 35, 36, 85–88, 105–108 for *Trigonella foenum-graecum* L.) would be expected to contribute markedly towards improving the ability of the treated plants for plant biomass production. This is borne out by the observed increase in plant fresh and dry weight (Tables 10, 19, 50, 51, 69, 70 for *Plantago ovata* Forsk. and 28, 37, 89, 90, 109, 110 for *Trigonella foenum-graecum* L.). The propositions presented above are further confirmed by correlation studies, highlighting a positive contribution of most of these growth parameters towards fresh and dry weight accumulation (Tables 120–127).

### 5.2 Physiological parameters

The reasons for the enhancing effect of basal application of nitrogen and phosphorus, in comparison with the no-nutrient control, on nitrogen content of *Plantago ovata* Forsk. plants in Experiments 1, 2, 5 and 6 (Tables 11, 20, 52, 71) and of phosphorus application on nitrogen and phosphorus content of *Trigonella foenum-graecum* L. plants in Experiments 3, 4, 7 and 8 (Tables 29, 38, 91, 92, 111, 112) at various growth stages are not far to seek. As no nutrients were applied to the control plants, they had to depend totally on the nutrients present in low concentration in the soil. On the other hand, treated plants got an adequate supply of these nutrients, ensuring continuous absorption by roots followed by smooth translocation to the foliage. This resulted finally in satisfactory distribution throughout the tops. An increase in the nitrogen content of *Plantago ovata* Forsk., as a result of combined application of nitrogen and phosphorus has also been noted by Khan (1988). Similarly, improvement in nitrogen and phosphorus content of leaves due to phosphorus application has been reported by Samiullah *et al.* (1984) for *Cymbopogon flexuosus*, and by Jat *et al.* (1998) and Kumawat *et al.* (1998) for *Trigonella foenum-graecum* L.

A decrease in the phosphorus content of *Plantago ovata* Forsk. was noted in Experiments 1, 2, 5 and 6 (Tables 11, 20, 53, 72) and in the potassium
content in Experiments 5 and 6 (Tables 54, 73) as a result of the combined basal application of nitrogen and phosphorus. A similar decline in the potassium content of *Trigonella foenum-graecum* L. due to phosphorus application was seen in Experiments 3, 4, 7 and 8 (Tables 29, 38, 93, 113). These observations may be attributed to the well known “dilution with growth effect”. It may be added that inspite of this observed decrease in the nutrient content and the non-significant effect of nitrogen and phosphorus application on the potassium content of *Plantago ovata* Forsk. (Tables 11, 20), their total uptake was enhanced (Tables 128, 129, 133-137 for *Plantago ovata* Forsk. and 130, 131, 140, 143 for *Trigonella foenum-graecum* L.). This increase in the nutrient uptake may be ascribed to higher dry matter production in treated plants (Tables 10, 19, 51, 70 for *Plantago ovata* Forsk. and 28, 37, 90, 110 for *Trigonella foenum-graecum* L.). An improvement in nitrogen and phosphorus uptake in *Plantago ovata* Forsk., grown with applied nitrogen and phosphorus, has also been reported by Patel *et al.* (1996b). Similarly, nitrogen, phosphorus and potassium uptake in *Trigonella foenum-graecum* L. has been noted to be enhanced due to the combined basal application of nitrogen, phosphorus and potassium by Detroja *et al.* (1995). Also noteworthy are the findings of Maliwal and Gupta (1990) who reported that basal phosphorus application increased the uptake of nitrogen and phosphorus by the crop. On the other hand, Dayanand *et al.* (1999) found only nitrogen uptake to be increased by the application of phosphorus to the soil.

The observed positive response to spray of gibberellic acid with regard to the nitrogen content of *Plantago ovata* Forsk. in Experiments 5 and 6 (Tables 52, 71) and also to that of nitrogen, phosphorus and potassium in *Trigonella foenum-graecum* L. in Experiments 7 and 8 (Tables 91–93, 111–113) may be ascribed to the stimulatory roles of gibberellic acid in various processes like accumulation of potassium in cytoplasm and plastids (Neumann and Janossy, 1977), enzyme activity (Seitz and Lang, 1968; Glasziou, 1969;
Broughton and McComb, 1971), membrane permeability (Wood and Paleg, 1972; 1974), mobilization and transport of organic or inorganic substances (De La Guardia and Benlloch, 1980; Ray and Choudhury, 1981) and utilization of nutrients (Ansari, 1996; Khan et al., 1997; Khan and Samiullah, 1997). This would result in increased synthesis of key organic molecules involved in nutrient uptake, transport and distribution and is thus reflected not only in the enhanced content but also uptake of these nutrients in Experiments 5, 6, 7 and 8 (Tables 132-143). An increase in phosphorus concentration in *Trigonella foenum-graecum* L. has also been reported by Tayal et al. (1978), and a similar increase in potassium content of the crop has been observed by Al-Wakeel et al. (1995).

In addition, increase in nitrogen and phosphorus content in *Triticum aestivum* L., as a result of pre-sowing seed treatment with gibberellic acid, has been reported by Haque et al. (1989). More relevantly, spray of gibberellic acid on *Trifolium alexandrinum* L. plants increased not only the leaf nitrogen and phosphorus content but also that of potassium (Agrawal et al., 1994).

The observed decrease in phosphorus and potassium content of *Plantago ovata* Forsk. due to foliar spray of gibberellic acid in Experiments 5 and 6 (Tables 53, 54, 72, 73) may again be ascribed to the “dilution with growth effect” as their uptake was found to have increased in the treated plants (Tables 133, 134, 136, 137), possibly due to higher dry matter production (Tables 51, 70). The case of *Trigonella foenum-graecum* L. is, however, slightly different. Here, the nitrogen, phosphorus and potassium contents were enhanced to such an extent that even increased dry matter production (Tables 90, 110) and consequent proportional increase in the uptake of the three nutrients (Tables 138-143) could not “dilute” their contents. It is noteworthy that a similar increase in nitrogen, phosphorus and potassium content and uptake has been reported by Agrawal et al. (1994) in *Trifolium alexandrinum* L. Incidentally, Khan et al. (1998) also reported an increase in the uptake of all three nutrients
in *Brassica juncea* L. due to gibberellic acid spray, inspite of their content being found non-significant.

The observed improvement in the nitrogen content of *Plantago ovata* Forsk. in Experiments 5 and 6 (Tables 52, 71) as a result of interaction of basal nitrogen and phosphorus with foliar spray of gibberellic acid, as also in the nitrogen, phosphorus and potassium content of *Trigonella foenum-graecum* L. in Experiments 7 and 8 (Tables 91–93, 111–113) due to the interaction between basal phosphorus and foliar gibberellic acid, may be assigned to the synergistic effect of the nutrients and of gibberellic acid as similar results were obtained when their individual effect was taken into consideration (Tables 52, 71, 91–93, 111–113). A similar increase in nitrogen, phosphorus and potassium content was noted to result from the combined application of nutrients and gibberellic acid as reported by Ansari (1996) for *Brassica juncea* L.

On the other hand, the observed decrease in the phosphorus and potassium content of *Plantago ovata* Forsk. in Experiments 5 and 6 (Tables 53, 54, 72, 73) when basal nitrogen and phosphorus interacted with leaf-applied gibberellic acid, may be attributed to the well known “dilution with growth effect”, as their uptake in *Plantago ovata* Forsk. due to combined application of nutrients and gibberellic acid was found to be increased (Tables 133, 134, 136, 137), possibly due to higher production of dry mater in treated plants (Tables 51, 70). In contrast to *Plantago ovata* Forsk., the uptake (Tables 138-143) as well as content of nitrogen, phosphorus and potassium (Tables 91-93, 111-113) were noted to be increased in *Trigonella foenum-graecum* L. A similar increase in nutrient uptake has also been reported by Ansari (1996) for *Brassica juncea* L.

Generally, there was an improvement in transpiration rate, stomatal conductance and net photosynthetic rate at 60, 90 and 120 DAS as a result of the application of nitrogen and/or phosphorus in comparison with the no-nutrient control in *Plantago ovata* Forsk. in Experiments 1, 2, 5 and 6 (Tables
as also in *Trigonella foenum-graecum* L. in Experiments 3, 4, 7 and 8 (Tables 30, 39, 94–96, 114–116).

The higher transpiration rate observed in treated plants of both crops, fertilized with nitrogen and/or phosphorus, was on expected lines since transpiration is known to depend on stomatal conductance (Johnson *et al.*, 1987; McMurtrie, 1993). The latter itself having shown considerable improvement in the treated plants, would, therefore, be expected to increase the rate of transpiration. In fact, this has been clearly established by correlation studies, a positive correlation (P=0.01) having been noted between these two parameters in almost all the eight experiments (Tables 120–127).

Improved photosynthesis in treated plants may be ascribed to the roles of nitrogen and phosphorus in the process. Nitrogen is an integral part of chlorophyll, enzymes and proteins (Marschner, 1986; Lynch and Rodriguez H., 1994) and improves “rubisco” content (Harmens *et al.*, 2000), which are known to contribute to carbon dioxide assimilation itself (Longstreth and Nobel, 1980; Lynch *et al.*, 1992). It also counteracts the photoinhibitory impacts and minimizes the effect of exposure to high light intensity in the photosynthetic system (Ramalho *et al.*, 1997). Like-wise, phosphorus is an integral part of many important metabolites (Devlin and Witham, 1986). It promotes ribulose-1, 5-bisphosphate regeneration (Rao and Terry, 1989; Fredeen *et al.*, 1990), ribulose-1, 5-bisphosphate carboxylase and adenosine triphosphate synthesis (Dietz and Foyer, 1986) and carbon dioxide assimilation (Longstreth and Nobel, 1980). Thus, these nutrients are directly or indirectly helpful in enhancing the photosynthetic process in treated plants, observed in the present study. These results corroborate the findings of Nair (1972), Longstreth and Nobel (1980), Dietz and Foyer (1986), Huber *et al.* (1989), Rao and Terry (1989), Fredeen *et al.* (1990), Lynch *et al.* (1992), Ramalho *et al.* (1997), Harmens *et al.* (2000) and Masarovičová *et al.* (2000).
Another contributing factor responsible for the increased rate of photosynthesis is prompt and adequate supply of carbon dioxide to the mesophyll cells of the plant and is controlled, to a large extent, by stomatal conductance. Wong et al. (1985a) also suggested that stomatal function may be controlled by mesophyll function. The fact that the treated plants of both crops showed higher values for stomatal conductance (Tables 12, 21, 30, 39, 56, 75, 95, 115) supported further by correlation studies, wherein photosynthesis showed a direct correlation with stomatal conductance (Tables 120–127) bears testimony to this relationship. Longstreth and Nobel (1980), Wong et al. (1985a, b), Johnson et al. (1987), Flanagan and Jefferies (1989), McMurtrie (1993) and del Blanco et al. (2000) have also reported a similar relation.

The observed enhancing effect of spray of gibberellic acid on transpiration rate, stomatal conductance and net photosynthetic rate at 60, 90 and 120 DAS of Plantago ovata Forsk. in Experiments 5 (Tables 55–57) and 6 (Tables 74–76) and Trigonella foenum-graecum L. in Experiments 7 (Tables 94–96) and 8 (Tables 114–116) may be ascribed to the roles of gibberellic acid noted earlier (pages 111, 114-115). For example, increase in the size of stomatal aperture and transpiration rate due to gibberellic acid treatment has been reported, among others, by Coulombe and Paquin (1959) in Lycopersicon esculentum L. and Livine and Vaadia (1965) in Hordeum vulgare Mill.

In addition, gibberellic acid spray improved not only the supply of metabolites required in the process of photosynthesis but also enhanced the activities of the numerous enzymes involved in the process. This assumption is further strengthened by the work of several researchers. For example, Saroop et al. (1994) observed an increase in the activity of photosystem I and photosystem II. Similarly, Khan (1996) and Hayat et al. (2001) noted a positive effect on carbonic anhydrase activity, whereas Arteca (1996) quotes the work of Wareing et al. (1968), Arteca and Dong (1981) and Hoad et al. (1977) who claimed a stimulatory effect on ribulose bisphosphate carboxylase/oxygenase
activity due to gibberellic acid treatment of other crops. The present data regarding photosynthesis also corroborate the findings of Coulombe and Paquin (1959), Wareing et al. (1968), Lester et al. (1972), Marcelle and Oben (1972), Gale et al. (1974), Marcelle et al. (1974), Borzenkova (1976), Chatterjee et al. (1976) and Erkan and Bangerth (1980).

The ameliorative interaction effect of basal application of nitrogen and phosphorus and foliar application of gibberellic acid (NP x GA) on the physiological parameters of Plantago ovata Forsk. in Experiments 5 (Tables 55–57) and 6 (Tables 74–76) and of phosphorus and gibberellic acid (P x GA) with regard to Trigonella foenum-graecum L. in Experiments 7 (Tables 94–96) and 8 (Tables 114–116) may be ascribed to the additive effect of nutrient/s and gibberellic acid discussed above.

5.3 Yield parameters


Increase in the leaf area (Tables 9, 18, 49, 68 for Plantago ovata Forsk. and 27, 36, 88, 108 for Trigonella foenum-graecum L.), on the one hand and in net photosynthetic rate (Tables 12, 21, 57, 76 for Plantago ovata Forsk. and 30,
39, 96, 116 for *Trigonella foenum-graecum* L.) on the other, seem to be mainly responsible for the observed parallel increase in the various yield parameters studied. The enhanced leaf area of the treated plants together with efficient radiant energy harvesting system enabled them to produce larger quantities of photosynthates as is clearly borne out by the higher dry weight of the treated plants (Tables 10, 19, 51, 70 for *Plantago ovata* Forsk. and 28, 37, 90, 110 for *Trigonella foenum-graecum* L.). The earlier mentioned adequate plant nitrogen, phosphorus and potassium content (Tables 11, 20, 52–54, 71–73 for *Plantago ovata* Forsk. and 29, 38, 91–93, 111–113 for *Trigonella foenum-graecum* L.), that elicited a positive response of various growth parameters to the application of nitrogen and/or phosphorus (Tables 6, 8, 9, 15, 17, 18, 42, 43, 46–49, 61, 62, 65–68 for *Plantago ovata* Forsk. and 24, 26, 27, 33, 35, 36, 80–82, 85–88, 100–102, 105–108 for *Trigonella foenum-graecum* L.), enhanced dry matter production by the treated plants (Tables 10, 19, 51, 70 for *Plantago ovata* Forsk. and 28, 37, 90, 110 for *Trigonella foenum-graecum* L.). Expectedly, this sequence of events led to a positive effect on the yield attributes in *Plantago ovata* Forsk. (Tables 13, 22, 58, 77), including swelling factor (Tables 14, 23, 60, 79) and in *Trigonella foenum-graecum* L. (Tables 31, 40, 97, 98, 117, 118). This sustained increase in yield attributes itself culminated expectedly in the maximization of seed yield (Tables 14, 23, 59, 78 for *Plantago ovata* Forsk. and 32, 41, 98, 118 for *Trigonella foenum-graecum* L.).

These above propositions are further confirmed by correlation studies wherein seed yield was found to be significantly and positively related to most of the characteristic studied, at various stages of growth of the two crops (Tables 120, 121, 124, 125 for *Plantago ovata* Forsk. and 122, 123, 126, 127 for *Trigonella foenum-graecum* L.). It may be added that the present findings regarding seed yield of *Plantago ovata* Forsk. corroborate the observations of Sirohi et al. (1970), Randhawa et al. (1978), Kalyanasundaram et al. (1982), Randhawa et al. (1982), Samra and Gill (1986), Ramesh et al. (1989), Singh et

Let us now consider the effect of foliar application of gibberellic acid that benefited not only the growth characteristics and physiological parameters, as mentioned earlier (pages 111, 114-115, 118-119), but also the yield attributing characteristics, seed yield and swelling factor, in *Plantago ovata* Forsk. (Tables 58-60, 77-79) and yield parameters in *Trigonella foenum-graecum* L. (Tables 97-99, 117-119). It is also noteworthy that, in general, most growth characteristics were found to be significantly and positively correlated with yield parameters, including seed and biological yield (Tables 120, 121, 124, 125 for *Plantago ovata* Forsk. and 122, 123, 126, 127 for *Trigonella foenum-graecum* L.). A similar ameliorating effect of gibberellic acid application has been noted by Anand and Sharma (1988) and Shahine et al. (1992) in *Trigonella foenum-graecum* L.

The noteworthy stimulatory interaction effect of soil-applied nitrogen and phosphorus and leaf-applied gibberellic acid (NP × GA) compared with their respective controls (N₀P₀ × GA₀) on yield parameters of *Plantago ovata* Forsk. in Experiments 5 (Tables 58-60) and 6 (Tables 77-79) and of soil-applied phosphorus and spray of gibberellic acid (P × GA) in *Trigonella foenum-graecum* L. in Experiments 7 (Tables 97–99) and 8 (Tables 117–119) may be ascribed to the additive effect of the two interacting factors (nutrient/s
and gibberellic acid). A somewhat similar observation has been made by Mukherjee and Prabhakar (1980), albeit in rice (*Oryza sativa* L.).

In the end, the present author wishes to claim, with all the modesty at his command, that he has been able to enrich the scientific literature on these two medicinal plants by contributing the following new findings.

**5.4 General observations:**

1. Pot experiments on *Plantago ovata* Forsk. and *Trigonella foenum-graecum* L., conducted to retrieve the entire undisturbed root system so as to allow precise physiomorphological studies, undertaken simultaneously with field trials on the two crops, furnished important data that were found complimentary to each other.

2. Data on the effectiveness of sources of phosphorus of different purity and chemical composition (1. laboratory grade diammonium phosphate applied to *Plantago ovata* Forsk. 2. sodium dihydrogen orthophosphate, to *Trigonella foenum-graecum* L. in pot culture and 3. commercial grade diammonium phosphate applied to *Plantago ovata* Forsk. and 4. monocalcium single superphosphate, to *Trigonella foenum-graecum* L. in field trials) broadly corroborated each other, implying that phosphorus played its expected positive role in the physiomorphology of the two crops, irrespective of its source.

3. Lastly, plausible explanations, based mainly on physiological considerations, have been given at appropriate places in the discussion regarding the entire data on the two crops collected by the author throughout the span of the present study.

**5.5 Specific crop-wise observations:**

**5.5.1 Plantago ovata** Forsk.

Application of basal nitrogen and phosphorus improved transpiration rate, stomatal conductance and net photosynthetic rate.
Gibberellic acid spray at 50 DAS improved growth attributing parameters; plant nitrogen content (but not that of phosphorus and potassium); uptake of nitrogen, phosphorus and potassium; transpiration rate; stomatal conductance and net photosynthetic rate (all noted at 60, 90 and 120 DAS) and yield attributing characteristics; seed yield and swelling factor (at harvest). The data were further refurbished by the detailed correlation studies undertaken. The same results were obtained convincingly when data for the interaction effect of basal nitrogen plus phosphorus and gibberellic acid spray were considered.

5.5.2 Trigonella foenum-graecum L.

Gibberellic acid spray at 50 DAS enhanced growth attributing characteristics; plant nitrogen as well as phosphorus and potassium content and uptake; transpiration rate; stomatal conductance and net photosynthetic rate (all noted at 60, 90 and 120 DAS). Detailed correlation studies, undertaken to establish relationships, not only strongly supported these findings but also established the contribution of the above characteristics to the yield attributing parameters and seed yield. Data regarding the interaction between basal phosphorus and gibberellic acid spray corroborated these findings beyond doubt.
CHAPTER 5 – DISCUSSION

It was mentioned in the thesis that no report on the interaction of nutrients with GA3 in these plants is available. Therefore, the discussion was based on the results available with the author. However, keeping the suggestions of the examiner, efforts would be concentrated to have more rational based discussion while publication of the data. Stomatal conductance and rate of photosynthesis are interrelated. Increase in stomatal conductance led to influx of CO2 in the intercellular spaces, which is used in the photosynthesis. Moreover, photosynthates formed in the process help to reduce resistance to air and increase stomatal conductance.