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Modelling Growth, Yield and Quality Attributes of *Salvia splendens* L. in Response to Various Nutrition Regimes

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Abstract

Salvia splendens (scarlet sage) is a popular specialty cut-flower worldwide. In Pakistan, it is grown as annual flower from spring to fall being used as bedding and border plant. A study was conducted at Rose Project Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, during 2014-2015, to evaluate the effect of various macronutrient applications alone or in various combinations on growth, yield and quality of *Salvia splendens* L. Experiment was set up in a randomized complete block design with eight treatments having twenty plants grown in each replication and all treatments were replicated thrice. Treatments included control (no fertilizer application), organic fertilizer (well rotten FYM at 1000 kg ha^{-1}), nitrogen (100 kg ha^{-1}), phosphorous (60 kg ha^{-1}), potassium (60 kg ha^{-1}), nitrogen + phosphorous, nitrogen + potassium and nitrogen + phosphorous + potassium. Salvia attained maximum plant height, leaf area, number of leaves per plant, number of lateral branches per plant, fresh and dry weight of plant and leaf nitrogen %age, when fertilized with nitrogen at 100 kg ha^{-1}. While stem diameter, flower diameter, leaf total chlorophyll contents, flower quality and vase life was highest in plants fertilized with N+P+K (100 + 60 + 60 kg ha^{-1}). N+P+K (100 + 60 + 60 kg ha^{-1}) application also shortened the production time and produced early flowering. Leaf P contents were maximum in plants fertilized with phosphorus at 60 kg ha^{-1}. Leaf K contents were highest in plants supplied with K at 60 kg ha^{-1}. Use of N alone or NPK improved plant growth and enhanced yield and quality, therefore, growers and nurserymen may use N at 100 kg ha^{-1} alone or NPK at 100 + 60 + 60 kg ha^{-1} for better growth, flowering and superior quality of cut *Salvia splendens* production.

INTRODUCTION

Salvia splendens, commonly known as scarlet sage, belongs to family Lamiaceae (Labiatae). It is a tender herbaceous, tap-rooted plant native to Brazil (Clebsch and Barner, 2003). Salvias are extremely pretty, bright, long-term flowers to adore in arrangements as cut-flowers or as annual flowering plants in lawns. Salvia has gained attention of many flower growers all over the world due to its wide range of dazzling and alluring hues. They produce color in the garden from summer to early fall when scarce blooming and more customary occasions held. Red salvias can form a stunning accent when used as bedding plant or lined up in a row edging plant, in rock gardens or in containers (Anonymous, 2015).

Floriculture is fast growing and highly competitive industry worldwide. The area under flower production in different countries of the world is about 305,105 ha, of which total area under Asia and pacific is about 215,386 ha. The world consumption of cut-flowers and plants is increasing annually 10 to 15 percent in all importing countries (Sudhagar, 2013). In Pakistan, production of cut-flowers is assessed at about 10-12 thousand tons per annum. Pakistan has incredible potential for production of cut-flowers and foliage plants on commercial scale due to accessibility of favourable soil and environmental conditions.

Plant nutrition is one of the most principal factors that influence positively plant growth (Sharma and Kumar, 2012). Superior quality flower production requires strong consideration for nutrients uptake. Management of inorganic nutrition is a critical factor in defining the ornamental value of the plants. Increased flower production, flower quality and fineness in the form of plant are the most important objectives to achieve in bedding and cut-flower production. Flower quality is a function of nutrient level (Boodley, 1975). Appropriate combination of fertilizers has a positive impact on quality flower production and long-lasting flowering period. The form of nutrients applied, rate of application and application time need utmost attention to inhibit nutrient scarcities from limiting vegetative growth and flower quality. Nitrogen, phosphorous and potassium are the most valuable essential nutrients, for enhancing quality and higher flower production of ornamentals (Kashif, 2001).

Nitrogen is the most limiting factor among all nutrients required for plant growth and development. Nitrogen plays an important role in the synthesis of plant constituents, which are critical for plant growth and dry matter yield. Nitrogen has a significant role in the initiation of meristematic activity of plants resulting in maximum plant height (Sarwar *et al*., 2013). It is widely accepted that deficient and over doses of nitrogen adversely affect plant growth (Sharma and Kumar, 2012). Main sources of N in plants are mineral N in soil, N applied as fertilizer or biological N_2 fixation (Konnerup and Brix, 2010). Nitrogen contributes to optimum growth when applied at correct rate and time.

Phosphorus is a fundamental element, which has a central position in energy transportation in protein and fat metabolism. Early maturity of crops, increased stem length, improved flower formation, seed production and development of roots has been related with the accessibility of phosphorus (Ahirwar *et al*., 2012). Its deficiency may consequence in smaller plants and shorter flowering stems.

Potassium provides strength and support to plant that plays important function in plant life. It improves drought resistance and increases root growth (Atwell *et al*., 1999). It decreases lodging, integrity of the cell membrane, controls plant turgidity and maintains the selectivity. Burning on the lower leaves first and marginal chlorosis are deficiency symptoms of Potassium (K).

Potassium minimizes water loss, supports translocation of starch and sugars, decreases wilting and respiration, aids in protein synthesis, raises the protein content of plants and prevents energy losses (Alam and Naqvi, 2003). Its deficiency in plant produces stunted growth and this stress may restrict flowering because the plant cells can’t divide to allow the growth and diminish the flower quality. Number of flowers decreases with deficiency of K (Dufault *et al*., 1990). N, P and K increase the vegetative growth and mobilize the process of flower development. Optimum levels of N, P and K application can increase flowering (Anamika and Lavania, 1990). Besides, an over application of fertilizer can result in excessive seedling size, nutrient toxicity and environmental contamination (van Iersel *et al*., 1998).

The specific objective of this study was to find out the optimum level of organic (FYM) and/or inorganic fertilizers (N, P and K) alone or various combinations for healthy plant growth and maximum production of superior quality cut stems of *Salvia splendens*.

MATERIALS AND METHODS

The study was conducted at Rose Project Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, during 2014-15. Seeds of *Salvia splendens* were purchased from a well reputed local agency and nursery was raised in plastic trays containing silt, coco coir and well rotten leaf manure (1:1:1; v/v/v) as substrate. Six weeks old healthy seedlings were transplanted in partially shaded greenhouse in thoroughly prepared soil beds. Urea (46%), single super phosphate (18%) and sulphate of potash (50%) were used as sources of N, P, and K. Full doses of P and K and half dose of N were applied at the time of soil preparation, while remaining half N dose was applied 30 days after transplant. Moreover, all other cultural practices, viz. irrigation, IPM, hoeing, weeding etc. were similar for all treatments during entire period of study. Experiment was set up in a randomized complete block design with eight treatments having twenty plants grown in each replication and all treatments were replicated thrice. Treatments included: control (no fertilizer application), organic fertilizer (well rotten FYM at 1000 kg ha^{-1}), nitrogen (100 kg ha^{-1}), phosphorous (60 kg ha^{-1}), potassium (60 kg ha^{-1}), nitrogen + phosphorous (100 + 60 kg ha^{-1}), nitrogen + potassium (100 + 60 kg ha^{-1}), and nitrogen + phosphorous + potassium (100 + 60 + 60 kg ha^{-1}). The study was conducted in a soil with 8.7 pH, 2.5 dS m^{-1} EC, 0.66% organic matter, 1.5% nitrogen, 9.7 mg kg^{-1} available phosphorus and 203 mg kg^{-1} available potassium. Soil samples were collected at the time of soil preparation and used for estimation of above mentioned characteristics. Data were collected on plant height (cm), number of leaves per plant, leaf area (cm^2), number of lateral branches per plant, leaf total chlorophyll contents (SPAD), production time (days), stem diameter (mm), flower diameter (mm), fresh weight of a plant (g), dry weight of a plant (g), vase life (days), leaf N contents (%), leaf P contents (mg kg^{-1}) and leaf K contents (mg kg^{-1}). Moreover, flower quality was assessed according to Cooper and Spokas (1991) and Dest and Guillard (1987) using a scale varied from 1 to 9 where, 1 = poor quality, 5 = medium quality and 9 = best quality.

All data were statistically analyzed using Fisher's analysis of variance technique and treatment means were compared using least significant difference test at 5% probability level (Steel *et al*., 1997).

RESULTS

Plants fertilized with N alone at 100 kg ha^{-1} produced tallest plants with 65.1 cm height (Figure 1a). Plants grown without any fertilizer (control) produced shortest plant height (52.7 cm). Data regarding number of leaves per plant revealed that plants fertilized with N alone at 100 kg ha^{-1} had maximum number of leaves per plant (106 leaves) (Figure 1B). Plants fertilized with P (60 kg ha^{-1}) exhibited minimum number of leaves per plant (56 leaves).

Comparison of treatment means revealed that plants fertilized with N (100 kg ha^{-1}) produced maximum leaf area (51.8 cm^2), where those without fertilization (control) produced smallest leaf area (39.6 cm^2) (data not presented). Regarding number of lateral branches per plant, plants fertilized with N (100 kg ha^{-1}) produced maximum number of lateral branches per plant (14 branches) (Table 1). Minimum number of lateral branches per plant (10 branches) was produced in plants fertilized with P at 60 kg ha^{-1}alone.

Data pertaining to leaf total chlorophyll contents demonstrated that plants fertilized with N + P + K (100 + 60 + 60 kg ha^{-1}) produced maximum leaf total chlorophyll contents (63.2 SPAD) (Table 1). Minimum leaf total chlorophyll contents were recorded (49.72 SPAD) in plants grown without fertilization (control).

Data regarding fresh weight of a plant revealed that plants fertilized with N alone at 100 kg ha^{-1} had maximum fresh weight of a plant (110.5 g) (Figure 1c). Plants fertilized with K alone at 60 kg ha^{-1} resulted in minimum fresh weight (41.6 g). Plants fertilized with N alone at 100 kg ha^{-1} produced maximum dry weight of a plant (20.6 g), (Figure 1d). While those fertilized with K at 60 kg ha^{-1} had minimum dry weight of a plant.

Plants fertilized with N+P (108 days) produced flowers in shortest production time, which was statistically at par with N + P + K (108 days) (Figure 1e). Plants fertilized with P (60 kg ha^{-1}) took maximum days to flowering (117 days). Data recorded on stem diameter exhibited that plants fertilized with N + P + K (100 + 60 + 60 kg ha^{-1}) had maximum stem diameter (6.5 mm) (Table 1). The plants having smallest stem diameter (5.3 mm) were fertilized with P alone at 60 kg ha^{-1}. Data pertaining to flower diameter illustrated that plants fertilized with N + P + K (100 + 60 + 60 kg ha^{-1}) had maximum flower diameter (63.4 mm) (Table 1). While those fertilized with P alone at 60 kg ha^{-1} resulted in minimum flower diameter (43.9 mm).

Results obtained on flower quality indicated that plants fertilized with N +P + K (100 + 60 + 60 kg ha^{-1}) produced superior quality flowers (7.6) (Figure 1f). Plants fertilized with organic fertilization produced poor quality flowers (5.6). Observations recorded on vase life disclosed that plants fertilized with N +P + K (100 + 60 + 60 kg ha^{-1}) had longest vase life (5.0 days) (Table 1). While plants with no fertilization (control) and those fertilized with P at 60 kg ha^{-1} had shortest vase life (3.0 or 3.2 days, respectively), and were statistically at par with each other.

Data collected on leaf N contents revealed that plants fertilized with N (100 kg ha^{-1}) had maximum leaf N contents (0.16%), while plants grown without fertilization had minimum leaf N contents (0.14%). Leaf P contents were highest (0.29 mg kg^{-1}) in plants fertilized with P (60 kg ha^{-1}). Minimum P contents were observed in plants fertilized with N (100 kg ha^{-1}), which were 0.01 mg kg^{-1}. Regarding leaf K contents, plants fertilized with K (60 kg ha^{-1}) had maximum leaf K contents (135 mg kg^{-1}), while those fertilized with N (100 kg ha^{-1}) had minimum leaf K contents (51 mg kg^{-1}) (data not presented).

DISCUSSION

It has been well established that maximum growth and best quality yield can be achieved by a combination of proper concentrations of nutrients along with growing substrate. Fertilization improved the plant growth and flower attributes of *Salvia splendens* by providing essential nutrients. Plants fertilized with N at 100 kg ha^{-1}

produced tallest plants with 65.1 cm height which confirmed the role of N in enhancing cell division and cell elongation leading to increased plant height. These results coincided with the findings of Verma *et al*. (2010) who reported that plant height and flower yield increased with application of N and P fertilizers in *Salvia sclarea*. Nitrogen is the principal nutritional element for plant vegetative growth. Plants fertilized with N (100 kg ha^{-1}) had maximum number of leaves per plant (106 leaves), which depicted that higher dose of N enhanced leaf cell number and size by increasing leaf biomass. Number of leaves in salvia might be influenced when grown under particular environmental conditions. These results are in line with the findings of Olaniyi and Ojetayo (2012) who reported that number of leaves and plant height were significantly increased by application of nitrogen on *Celosia argentea*.

Regarding leaf area, fertilizer treatments had no comparable pattern for different fertilizer applications. Comparison of treatments means revealed that plants fertilized with N (100 kg ha^{-1}) produced greater leaf area (51.8 cm^2). Similar trends have also been reported by Qasim *et al*. (2005) who described that supply of nitrogen at 30 g per plant increased leaf area in *Rosa chinensis* Gruss-an-teplitz. Plants fertilized with N (100 kg ha^{-1}) produced maximum number of lateral branches per plant (14 branches). Nitrogen plays an essential role in the synthesis of plant constituents. Optimum supply of nitrogen is directly proportional to the growth rate. These results confirmed the findings of Ahmad *et al*. (2010) who demonstrated that N, P and K fertilizer application produced maximum number of lateral branches in *Tagetes patula* 'Yellow' and *Tagetes erecta* 'Double Eagle'.

Plants fertilized with N + P + K (100 + 60 + 60 kg ha^{-1}) produced maximum leaf total chlorophyll contents (63.2 SPAD). Higher leaf total chlorophyll contents in plants may be due to climatic factors like availability of sunlight, which was absorbed by the plant in excess. As a result of maximum photosynthetic activity, higher amount of photosynthates accumulated in the leaves. These results are in alliance with the findings of Ali *et al*. (2014) who reported that N, P and K at 17:17:17 produced maximum leaf total chlorophyll contents in *Tulipa gesneriana*.

Best results regarding production time were recorded in plants fertilized with N+P and N + P + K (100 + 60 + 60 kg ha^{-1}) (108 days each). NPK alone or in various combinations provided balanced nutrition for early flowering. Early maturity of crops and development of roots has been related with the accessibility of phosphorus. It encouraged rapid growth and early flowering. These results are in accordance to the findings of Omaha (2004) who reported that *zinnia elegans* performed best regarding production time when grown in soil with high phosphorous and low nitrogen application.

Data recorded on stem diameter and flower diameter exhibited that plants fertilized with N + P + K (100 + 60 + 60 kg ha^{-1}) had maximum stem diameter (6.5 mm) and flower diameter (63.4 mm). Application of NPK significantly increased stem and flower diameter. NPK fertilizer increased flower growth and quality because they have stimulatory and catalytic effect in different processes of plant growth and development. Maximum flowering as well as increase in flower diameter indicated the best use of fertilization. These results confirmed the findings of Kashif *et al*. (2014) who demonstrated that N, P and K fertilization increased flower diameter in *Dahlia hybrida*. Ali *et al*. (2014) observed that NPK (17:17:17) was the most beneficial for increased stem diameter in *Tulipa gesneriana*.

Results regarding to fresh and dry weight of plant demonstrated that plants fertilized with N (100 kg ha^{-1}) had maximum fresh and dry weight of a plant (110.5 and 20.6 g, respectively). Nitrogen is the principal nutritional element for plant vegetative growth. Abundant supply of nitrogen increased cell size and cell number as a result of cell division and cell enlargement leading to tallest stem length, longest branches and highest number of leaves. These results are in line with the findings of Alkurdi (2014) who reported that nitrogen and phosphorus fertilization improved fresh and dry weight of *Helichrysum bractum*.

Results obtained on flower quality indicated that plants fertilized with N +P + K (100 + 60 + 60 kg ha^{-1}) produced superior quality flowers (7.6). Rich supply of nutrients such as N, P and K in growing substrates is sufficient for production of good quality flowers. P contents in growing substrate affects the quality of flowers. These results are in similarity with the findings of Munichaluvaiah *et al*. (2004) who reported that application of NPK resulted in best quality flower of gladiolus. Plants fertilized with N +P + K (100 + 60 + 60 kg ha^{-1}) had longest vase life (5.0 days). Accumulation of carbohydrates leads towards continued freshness of flowers for longer periods. The increased rates of nitrogen application might have permitted lesser accumulation of carbohydrates in the flower stalks due to more vegetative growth, which might have led to enhanced senescence than those with lower nitrogen application. These results are in accordance with the findings of Indrajit and Nilimesh (2003) who revealed that application of nitrogen and phosphorus resulted in increased number of flowers, longest duration of flowering and vase life in carnation.

Results regarding leaf N contents revealed that plants fertilized with N (100 kg ha^{-1}) had higher leaf N contents (0.16%). Increased nitrogen levels maximized plant nitrogen concentration due to high availability of nitrogen and better uptake of nitrogen by plants. These results are in contrast to the findings of Khalaj *et al*. (2012) who concluded that increased levels of nitrogen on tuberose (*Polianthes tuberosa*) lowered leaf N contents. Information secured on leaf P contents revealed that maximum leaf P contents (0.29 mg kg^{-1}) were recorded in plants fertilized with P (60 kg ha^{-1}). These results are in line with the results of Sarwar *et al*. (2013) who reported that application of NPK increased leaf N contents, P contents and K contents in leaves of stock (*Matthiola incana*). Results regarding leaf K contents presented that plants fertilized with K (60 kg ha^{-1}) had maximum leaf K contents (135 mg kg^{-1}). These results are in accordance with the findings of Zhang *et al*. (2012) who demonstrated leaf K contents, their accumulation and distribution traits in *Petunia hybrida*.

In summary, application of N alone or in combined form as NPK improved plant growth and increased flower yield and quality of *Salvia splendens* and may be used by growers and nurserymen for producing best quality salvia plants and cut stems.

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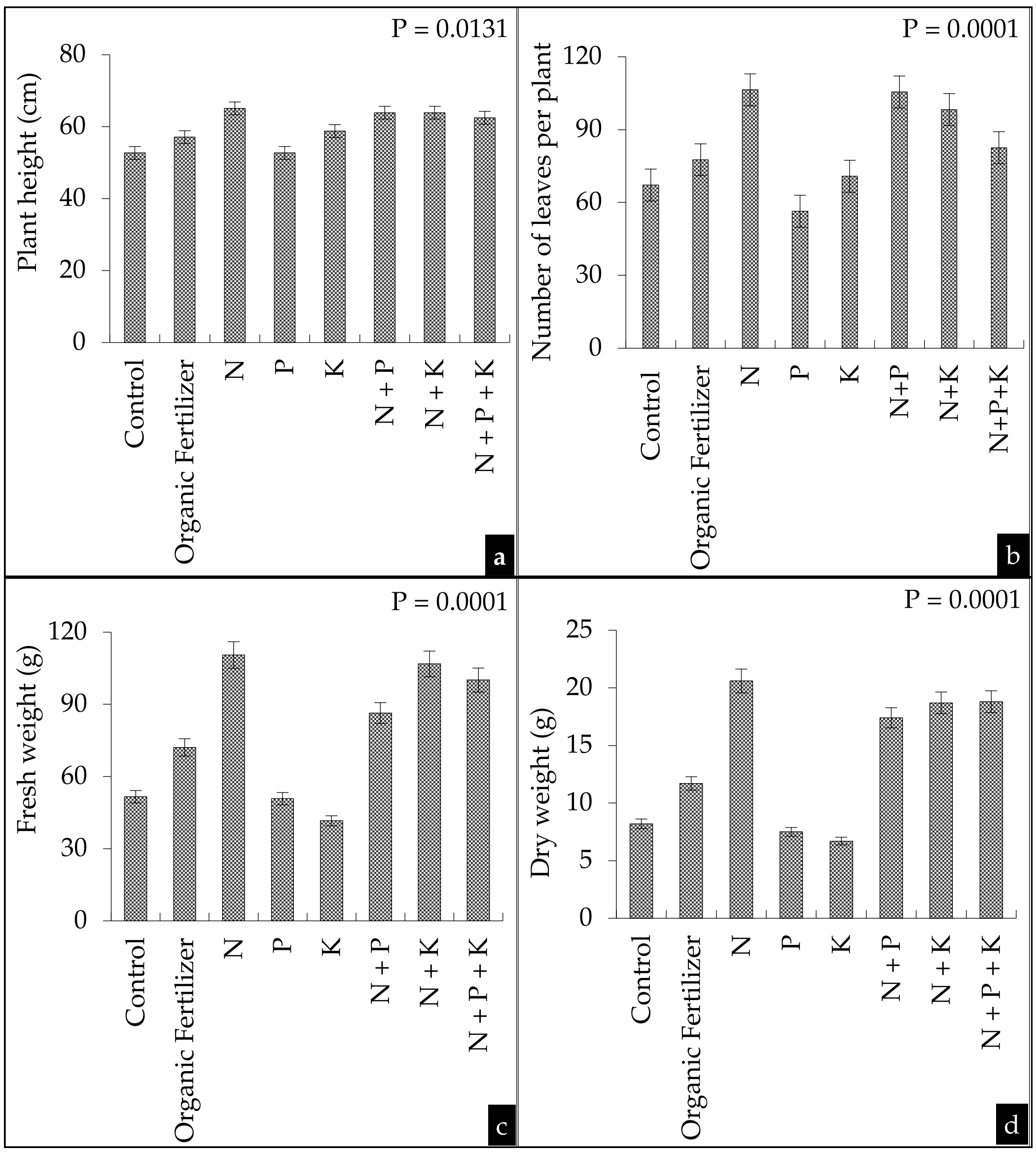

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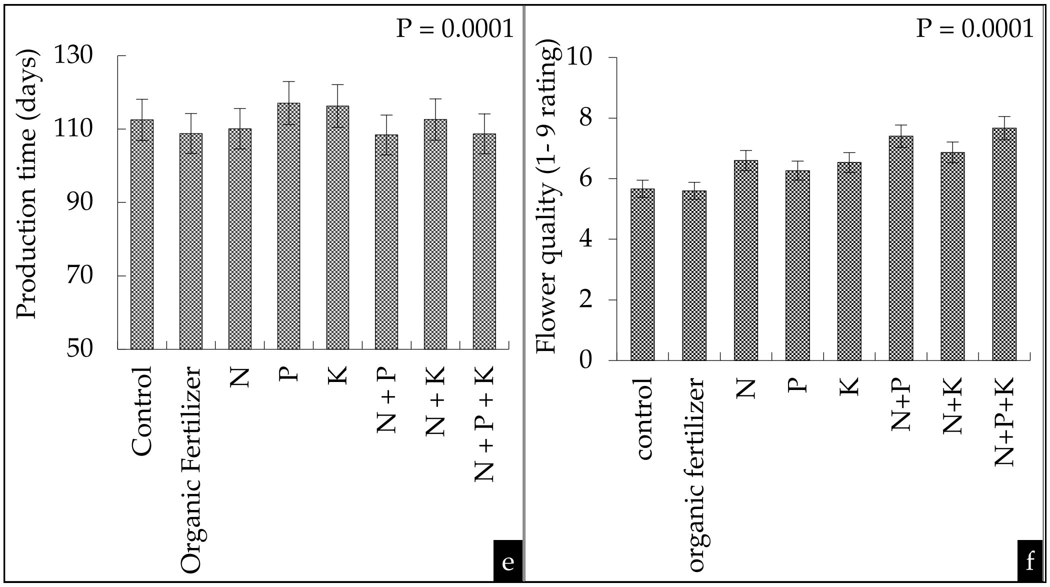

Figure 1: Plant height (a), number of leaves (b), plant fresh weight (c), plant dry weight (d), production time (e) and flower quality (f) of *Salvia splendens* as influenced by NPK alone or in various combinations. Bars represent means of 15 samples ±S.E.

Table 1: Leaf total chlorophyll contents, number of lateral branches per plant, stem diameter, flower diameter and vase life of *Salvia splendens* as influenced by organic fertilization or NPK alone or in various combinations. Data represent means of 15 plants.

Treatments	**Leaf total chlorophyll contents (SPAD)**	**Number of lateral branches per plant**	**Stem diameter (mm)**	**Flower diameter (mm)**	**Vase life (days)**
Control	49.7 e[z]	11.5 cd	5.4 bc	56.1 ab	3.21 d
Organic Fertilizer	55.2 bcd	12.0 cd	6.4 a	54.5 abc	4.2 bc
N	57.1 bc	14.6 a	5.9 abc	54.5 abc	4.0 c
P	53.9 cde	10.4 d	5.3 c	43.9 c	3.2 d
K	50.5 de	12.6 bc	6.0 ab	47.4 bc	3.9 cd
N + P	62.4 a	13.7 ab	6.3 a	57.8 ab	4.7 ab
N + K	59.4 ab	14.0 ab	6.2 a	52.4 bc	3.8 cd
N + P + K	63.2 a	13.0 bc	6.5 a	63.4 a	5.0 a
Significance[y]	$P < 0.0001$	$P < 0.0001$	$P < 0.0018$	$P < 0.0210$	$P < 0.0001$

[z] Mean separation within columns by Fisher's LSD at $P \leq 0.05$.
[y] P values were obtained using General Linear Models (GLM) procedures of Statistix 8.1 for significant effects of fertilizer applications.