Effect of plant spacings, NPK fertilization levels and their interaction on vegetative growth, flowering and some active ingredients of *Verbascum thapsus* L. under sandy soil conditions

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Abstract: The present work aimed to study the effects of plant spacings, NPK fertilization levels and their interaction on vegetative growth, flowering and some active ingredients of common mullein (*Verbascum thapsus* L.) plants under sandy soils conditions. Three spacings at 20, 30 and 40 cm between the plants in row and four levels of NPK fertilization at 0.0:0.0:0.0, 20.5:15.5:24, 41:31:48, and 61.5:46.5:72 kg/fed. of N: P_2O_5: K_2O, respectively were applied. Generally, the highest yield of dry leaves and dry flowers per plant as well as the highest content of some active components in leaves and flowers (total iridoid glycosides, total saponins and total mucilages) were obtained from using the highest levels of each of plant spacing and NPK fertilization alone or in combination. Whereas, the highest yields of dry leaves and dry flowers per feddan as well as the active components were produced with the narrow spacing (20) cm combined with the highest level of NPK fertilization in both seasons.

Keywords: *Verbascum thapsus*, Plant spacing, chemical fertilization.

INTRODUCTION

Verbascum thapsus L., Family: Scrophulariaceae (Figwort family) is native to Europe and Asia and was probably introduced into North America several times as a medicinal herb (Semenza *et al.*, 1978). This plant is a biennial, rarely cultivated as an annual plant (Gross and Werner, 1978). In Egypt, this plant grows as an annual plant.

The common names of *Verbascum thapsus* L. include mullein, common mullein, great mullein, wooly mullein and others. This plant is a herb with along history of use in folk medicine. Mullein leaves and flowers have expectorant and demulcent properties which are used by herbalists to treat respiratory problems such as bronchitis, dry coughs, whooping cough, tuberculosis, asthma and hoarseness (Mabey, 1988 and Berk,1996).

The constituents of *Verbascum thapsus* L. include polysaccharides, iridoid glycosides including harpagoside; harpagide and aucubin (especially in the leaf); flavonoids including 3-methylguercitin, hesperedin and verbascoside; saponins and volatile oils (Mehrotra *et al.*, 1989 and Warashina *et al.*, 1992).

Proper manipulation of cultural practices appeared to play a major role in promotion of the growth and the accumulation of active ingredients in plant organs. It is well known that vegetative characteristics, flowering and contents of active ingredients of the medicinal plants are directly related to planting distances. The optimum plant density can occupy a unit area in order to get more and highly photosynthesis system to change the received light energy to chemical energy. Also, it affects the plant number per unit area which is reflected on the total yield per feddan (unit area).

In this concern, Mahmoud (1980) studied the effect of three culture spacings of 25, 50 and 75 cm on mullein (*Verbascum thapsus* L.) in a sandy soil supplemented with loamy-clay and organic materials and reported that vegetative growth as well as flowers yield were significantly improved by increasing the spacing between plants. In contrast, flower yield per feddan was increased as spacing decreased. The wide spacing (75 cm) recorded the highest content of mucilages in the leaves and flowers as well as the highest percentage of saponins in the flowers. Also, Kleitz *et al.* (2003) showed that *Verbascum thapsus* plants had the highest plot yield at the narrowest spacing (12 inch).

On the other side, Verkaar *et al.* (1986) on *Verbascum thapsus* found that at high levels of nitrogen supply, there was a higher net assimilation rate (NAR) and a higher leaf weight ratio in defoliated plants than in undefoliated ones, resulting in faster growth of defoliated plants. Salama *et al.* (2003) indicated that the mineral nitrogen source enhanced the growth and biomass production of *Verbascum thapsus*. All nitrogen levels increased flower yield/plant. The highest level of mineral nitrogen (100.5 kg/fed.) gave the highest total iridoid glycosides content and total mucilages percentage in the leaves and flowers. In this respect, Chalapathi *et al.* (1999) showed that stevia (*Stevia rebaudiana* Bertoni) growth and yield were significantly increased with increasing NPK fertilization rates. Roki *et al.* (2001) revealed that NPK increased the flower yield of *Arnica chamissonis*. Nandi and Chatterjee (1991) cleared that increasing NPK fertilization increased the total glycosides in leaves of *Digitalis lanata* and *Digitalis purpurea* plants. Hammam (2002) on senna (*Cassia acutifolia*, Delile) found that all NPK treatments increased plant height, fresh and dry weights per plant and per feddan as well as the sennosides yield in leaves/plant.

The aim of this work is to investigate the effects of plant spacings, NPK fertilization levels and their interaction treatments on vegetative growth, flowering and some active ingredients of common mullein (*Verbascum thapsus* L.) plants under sandy soil conditions.

MATERIALS AND METHODS

This work was carried out at the Experimental Farm of Horticulture Research Station in El-Quassasin, Ismailia Governorate, Egypt, during the two successive seasons of 2005-2006 and 2006-2007. The experimental soil in the two seasons was sandy soil and its physical and chemical properties are shown in Table (1). The irrigation during the two seasons was taken from the same source.

Seeds of *Verbascum thapsus* L. were obtained from Sekam Company, Cairo, Egypt. The seeds were sown in the nursery on 30th and 25th September in the two seasons of 2005 and 2006, respectively in foam trays (209 eyes) containing sand: peat: vermiculite at 1:1:1 ratio (v: v: v). On 15th and 11th November in the two seasons, respectively, uniform seedlings at 45 days age (about 15 cm. length) were transplanted in a sandy soil with 60 cm between the rows. The experimental unit area was 2.4 m^2 (0.6 X 4 m.), and the whole experiment has 36 plots.

Three spacings between the plants in the row as 20, 30 and 40 cm were used. Also, four chemical fertilization treatments (NPK) included nitrogen; phosphorus and potassium at four levels ($N_0P_0K_0$, $N_1P_1K_1$, $N_2P_2K_2$, and $N_3P_3K_3$) were studied. Ammonium sulphate (20.5 % N) was used as a source of nitrogen at the rates of 0.0, 100, 200 and 300 kg/fed., equal to 0.0 (N_0), 20.5 (N_1), 41 (N_2) and 61.5 (N_3) kg N/feddan. Calcium super phosphate (15.5 % P_2O_5) was used as a source of phosphorus at the rates of 0.0, 100, 200 and 300 kg/fed., equal to 0.0 (P_0), 15.5 (P_1), 31(P_2) and 46.5 (P_3) kg P_2O_5/feddan. Potassium sulphate (48 % K_2O) was used as a source of potassium at the rates of 0.0, 50, 100 and 150 kg/fed., equal to 0.0 (K_0), 24 (K_1), 48 (K_2) and 72 (K_3) kg K_2O/fed. So the treatments with NPK fertilization were as follows:

- $N_0P_0K_0$ (0.0, 0.0 and 0.0 kg N, P_2O_5 and K_2O/fed.) (Control).
- $N_1P_1K_1$ (20.5, 15.5 and 24 kg N, P_2O_5 and K_2O/fed.).
- $N_2P_2K_2$ (41.5, 31.0 and 48 kg N, P_2O_5 and K_2O/fed.).
- $N_3P_3K_3$ (61.5, 46.5 and 72 kg N, P_2O_5 and K_2O/fed.).

The phosphorus fertilizer was added to the soil during the preparation process at the ridges and covered with the soil. This process was carried out three weeks before transplanting. In both seasons, nitrogen and potassium fertilizers were applied as a soil dressing beside plants at three equal doses, the first dose was applied after one month from transplanting, and the other two doses were applied at one month intervals. All plants received normal agricultural practices whenever they needed.

At the beginning of flowering stage during March of each season, the following data as: number of leaves per plant, fresh and dry weights of leaves per plant (g) were recorded. The yield of dry leaves per feddan (ton) was calculated by multiplying dry weight of leaves/plant by number of plants/feddan, while, plant height (cm) was recorded in the end of the flowering stage (harvest time in June). Meantime, the fresh flowers were daily collected from certain plants till the end of flowering. The daily yields of fresh flowers were weighed, then dried and at the end of season, the total yield was collected to obtain the fresh and dry weight of flowers per plant (g.). The yield of dry flowers per feddan (ton) was calculated at the end of flowering stage by multiplying dry weight of flowers/plant by plant number/feddan.

Table (1): The physical and chemical properties of the used soil in the two seasons.

Properties	First season	Second season
Physical properties :		
Sand (%)	91.5	92
Silt (%)	1.5	1.0
Clay (%)	7.0	7.0
Texture	Sandy	Sandy
Chemical properties :		
Salt analysis :		
EC dS_m^{-1}	0.62	1.12
pH	7.12	7.51
Cations (meq/l) :		
Ca^{2+}	1.8	1.0
Mg^{2+}	0.8	0.4
Na^{+}	2.7	5.2
K^{+}	0.8	4.6
Anions (meq/l) :		
Cl^{-}	0.6	5.6
$HCO_3^{-}+CO_3^{2-}$	1.8	1.0
SO_4^{2-}	3.7	4.6
Available elements :		
Nitrogen (mg/kg)	14.0	28.0
Phosphorus (mg/kg)	16.4	25.8
Potassium (mg/kg)	252	379
Total nitrogen (g/kg)	0.28	0.28
Organic matter (OM) (%)	0.32	0.50

For chemical analysis, total iridoid glycosides (T.I.G) content (mg/100 g dry matter) and total saponins (T.S) percentage in the leaf and flower samples were colorimetrically determined according to the methods of Kotenko *et al.* (1994) and Ebrahimzadah and Niknam (1998), respectively. However, total mucilages (T.M) percentage in the leaf and flower samples was determined according to the method described by Karawya *et al.* (1980).

The factorial experiment was arranged in a randomized complete block design in three replicates and the collected data were computed and statistically analyzed with the analysis of variance using Mstat program. The differences between the means of treatments were tested using Duncan Multiple Range Test at 0.05 level according to Jayaraman (1999).

RESULTS AND DISCUSSION

Effect of plant spacings on some vegetative growth parameters:

The results presented in Table (2) show that increasing spacing between plants from 20 to 40 cm resulted in a significant decrease in plant height, as the tallest plants (222.83 and 221.58 cm) were obtained with 20 cm spacing during the first and second seasons, respectively.

The leaf number of *Verbascum thapsus* plant recorded significant increase by increasing plant spacing (Table, 2). The wide spacing (40 cm) significantly gave the highest number of leaves/plant as 19.21 and 23.46 leaves with increment over the narrow one (20 cm) by 12.14 and 12.37% in the two seasons, respectively. A similar trend of results was reported by Mahmoud (1980) on *Verbascum thapsus*. Similar results were obtained with the fresh and dry weight of leaves/plant, where the wide spacing (40 cm) significantly produced the heaviest fresh weight of leaves as 330.78 and 409.29 g. and as 70.18 and 82.42 g. for dry leaves in the first and second seasons, respectively (Table, 2). These results are in harmony with those reported by Mahmoud (1980) on common mullein.

Such increase in number and weight of leaves/plant at the wide spacing may be due to the lower competition between plants which led to more utilization of light, water and nutrients and subsequently increase accumulation rate of nutrients which reflected on increasing the plant growth parameter.

The yield of dry leaves per feddan of mullein was also significantly decreased as spacing increased (Table, 2). The narrow spacing (20 cm) exhibited the highest yield of 2.26 and 2.47 tons of dry leaves/fed. in the first and second seasons, respectively. The yield of dry leaves/plant as well as per feddan was lower in the first season than that in the second one.

The positive effect of closer spacing on the yield of dry leaves per feddan may be due to the increase in cultivated plants per unit area which reflected on producing the heaviest dry weight of leaves per feddan.

Effect of NPK fertilization levels on some vegetative growth parameters:

The presented results in Table (2) reveal that plant height of common mullein was increased as NPK fertilization levels increased, and the highest level of NPK fertilization ($N_3P_3K_3$) gave the tallest plants with significant differences compared to the other treatments or control in both seasons. Similar results were showed by Salama *et al.* (2003) on mullein and Hammam (2002) on senna.

The results given in Table (2) clear that NPK levels recorded significant increase in leaf number/plant of *Verbascum thapsus* comparing with the control with significant differences. In this respect, the highest level ($N_3P_3K_3$) exhibited the highest leaf number/plant as 20.37 and 25.06 leaves for both seasons, respectively. These results agreed with those found by Salama *et al.* (2003) on common mullein.

Moreover, the highest level ($N_3P_3K_3$) significantly resulted in the highest values of fresh and dry weight of leaves compared to the other levels (Table, 2). This treatment gave an increase over control by 86.64 and 113.94% of fresh leaves and by 62.01 and 78.29% of dry leaves weight in the first and second seasons, respectively. The same treatment produced the heaviest yield of dry leaves/fed. In this concern, Chalapathi *et al.* (1999) and Hammam (2002) reported that NPK application increased the fresh and dry weight of stevia and senna, respectively also Salama *et al.* (2003) reported that N application increased the fresh weight of *Verbascum thapsus* leaves.

This increase in the growth of Verbascum plants may be due to the direct or indirect role of NPK in plant anabolism through activating the photosynthetic processes as well as the accumulation of their metabolites in plant organs, resulting in more plant materials.

Effect of the interaction between plant spacings and NPK fertilization levels on some vegetative growth parameters:

From the data in Table (2) it can be concluded that the plant height of *Verbascum thapsus* during the two seasons was increased by increasing NPK fertilization levels with decreasing plant spacing with non significant differences in most cases. Moreover, the interaction between 20 cm spacing and $N_3P_3K_3$ level resulted in the tallest plants as 233.11 and 232.89 cm in the first and second seasons, respectively, whereas, the shortest plants were obtained with the wide spacing at 40 cm alone (without fertilization) as 204.33 and 205.33 cm in both seasons, respectively.

Moreover, the interaction between plant spacing and NPK fertilization levels gave significant increase in leaf number/plant compared to the plant spacing without NPK fertilization. The highest level of NPK ($N_3P_3K_3$) combined with the wide spacing (40 cm) significantly recorded the highest number of leaves as 21.78 and 26.11 leaves in the two seasons, respectively.

Data shown in Table (2) clearly indicate that the fresh and dry weights of leaves per plant were increased by increasing plant spacing and NPK fertilization levels together. The interaction treatment between 40 cm spacing and $N_3P_3K_3$ level recorded the heaviest fresh weight of leaves as 420.94 and 542.26 g and the heaviest dry weight of leaves at 85.43 and 103.11g in both seasons, respectively.

The yield of dry leaves/feddan recorded significant increase by increasing the levels of NPK fertilization with decreasing plant spacing. Likewise, the highest level of NPK fertilization ($N_3P_3K_3$) combined with the narrow spacing of 20 cm gave the highest yield of dry leaves as 2.86 and 3.27 ton/fed. in the two seasons, respectively (Table, 2).

Effect of plant spacings on some flowering parameters:

Data in Table (3) show that the fresh and dry weights of flowers were significantly increased by increasing plant spacing. Moreover, the widest spacing (40 cm) gave significant increases in fresh and dry weight of flowers/plant compared to the other two spaces during the two seasons. Plant yield of fresh and dry flowers/plant was higher in the second season than in the first one. These results are in line with those stated by Mahmoud (1980) on mullein.

In contrast, the yield of dry flowers per feddan was significantly decreased by increasing spacing between plants and the narrow spacing (20 cm) significantly increased the dry flower yield during both seasons. These results are in harmony with those obtained by Mahmoud (1980) and Kleitz *et al.* (2003) on mullein.

Table (2): Effect of plant spacings, NPK fertilization levels and their interaction on some vegetative growth parameters of *Verbascum thapsus* L. during seasons 2005-2006 and 2006-2007.

Treatments		First season					Second season				
Plant spacing	NPK fertilization (kg/fed.)	Plant height (cm)	Number of leaves/plant	Fresh weight of leaves/ plant (g)	Dry weight of leaves/ plant (g)	Yield of dry leaves/ fed.(ton)	Plant height (cm)	Number of leaves/plant	Fresh weight of leaves/ plant (g)	Dry weight of leaves/ plant (g)	Yield of dry leaves/ fed.(ton)
20 cm	$N_0P_0K_0$	211.2 ^{efg}	14.61 ^{i}	196.57 ^{i}	48.35 ^{i}	1.69 ^{e}	209.9 ^{g}	17.78 ^{h}	217.99 ^{l}	51.67 ^{l}	1.81 ^{f}
	$N_1P_1K_1$	218.7 ^{cde}	16.78 ^{g}	264.76 ^{g}	60.23 ^{g}	2.11 ^{c}	216.4 ^{e}	19.83 ^{f}	299.73 ^{i}	64.95 ^{i}	2.27 ^{d}
	$N_2P_2K_2$	227.9 ^{ab}	17.83 ^{ef}	311.81 ^{ef}	67.66 ^{e}	2.37 ^{b}	227.2 ^{c}	22.33 ^{d}	341.22 ^{g}	71.75 ^{g}	2.51 ^{b}
	$N_3P_3K_3$	233.1 ^{a}	19.28 ^{c}	377.59 ^{bc}	82.01 ^{b}	2.86 ^{a}	232.9 ^{a}	23.83 ^{c}	481.90 ^{c}	93.52 ^{c}	3.27 ^{a}
30 cm	$N_0P_0K_0$	209.3 ^{fg}	15.83 ^{h}	210.55 ^{hi}	50.12 ^{i}	1.17 ^{i}	207.9 ^{h}	19.06 ^{g}	226.10 ^{k}	52.47 ^{k}	1.23 ^{j}
	$N_1P_1K_1$	216.3 ^{def}	17.33 ^{f}	277.65 ^{fg}	61.57 ^{g}	1.44 ^{g}	213.3 ^{f}	21.67 ^{e}	318.12 ^{h}	68.64 ^{h}	1.60 ^{g}
	$N_2P_2K_2$	226.2 ^{abc}	18.67 ^{d}	330.91 ^{de}	71.12 ^{d}	1.66 ^{e}	225.6 ^{d}	23.66 ^{c}	413.36 ^{e}	82.66 ^{e}	1.93 ^{e}
	$N_3P_3K_3$	229.7 ^{ab}	20.06 ^{b}	410.99 ^{ab}	83.05 ^{ab}	1.94 ^{d}	231.9 ^{ab}	25.22 ^{b}	525.15 ^{b}	99.24 ^{b}	2.32 ^{c}
40 cm	$N_0P_0K_0$	204.3 ^{g}	16.61 ^{g}	240.94 ^{gh}	55.67 ^{h}	0.97 ^{j}	205.3 ^{i}	20.39 ^{f}	280.08 ^{j}	61.81 ^{j}	1.08 ^{k}
	$N_1P_1K_1$	210.4 ^{fg}	18.22 ^{de}	327.01 ^{de}	64.39 ^{f}	1.13 ^{i}	212.3 ^{f}	22.83 ^{d}	364.61 ^{f}	76.97 ^{f}	1.35 ^{i}
	$N_2P_2K_2$	221.8 ^{bcd}	20.22 ^{b}	367.55 ^{cd}	75.22 ^{c}	1.32 ^{h}	224.9 ^{d}	24.78 ^{b}	450.19 ^{d}	87.77 ^{d}	1.54 ^{h}
	$N_3P_3K_3$	228.8 ^{ab}	21.78 ^{a}	420.94 ^{a}	85.43 ^{a}	1.50 ^{f}	230.8 ^{b}	25.83 ^{a}	542.26 ^{a}	103.0 ^{a}	1.80 ^{f}
Main effect of plant spacing	20 cm	222.7 ^{a}	17.12 ^{c}	287.68 ^{b}	64.56 ^{c}	2.26 ^{a}	221.6 ^{a}	20.94 ^{c}	335.21 ^{c}	70.47 ^{c}	2.47 ^{a}
	30 cm	220.3 ^{a}	17.97 ^{b}	307.52 ^{b}	66.47 ^{b}	1.55 ^{b}	219.7 ^{b}	22.40 ^{b}	370.68 ^{b}	75.75 ^{b}	1.77 ^{b}
	40 cm	216.3 ^{b}	19.21 ^{a}	339.11 ^{a}	70.18 ^{a}	1.23 ^{c}	218.3 ^{c}	23.46 ^{a}	409.29 ^{a}	82.39 ^{a}	1.44 ^{c}
Main effect of NPK	$N_0P_0K_0$	208.3 ^{d}	15.68 ^{d}	216.02 ^{d}	51.38 ^{d}	1.28 ^{d}	207.7 ^{d}	19.07 ^{d}	241.39 ^{d}	55.31 ^{d}	1.37 ^{d}
	$N_1P_1K_1$	215.1 ^{c}	17.44 ^{c}	289.81 ^{c}	62.06 ^{c}	1.56 ^{c}	214.0 ^{c}	21.44 ^{c}	327.49 ^{c}	70.19 ^{c}	1.74 ^{c}
	$N_2P_2K_2$	225.3 ^{b}	18.91 ^{b}	336.76 ^{b}	71.33 ^{b}	1.78 ^{b}	225.9 ^{b}	23.59 ^{b}	401.59 ^{b}	80.73 ^{b}	1.99 ^{b}
	$N_3P_3K_3$	230.5 ^{a}	20.37 ^{a}	403.17 ^{a}	83.50 ^{a}	2.10 ^{a}	231.9 ^{a}	24.96 ^{a}	516.44 ^{a}	98.59 ^{a}	2.46 ^{a}

*Means in the same column with the same letters are not significantly different at $p < 0.05$ according to Duncan's multiple range test.

Effect of NPK fertilization levels on some flowering parameters:

From Table (3) it can be concluded that raising NPK fertilization level increased the fresh and dry weight of flowers/plant with significant differences in this respect. The highest level of NPK fertilization ($N_3P_3K_3$) significantly produced the heaviest fresh weight of flowers as 512.54 and 523.15 g and the heaviest dry weight as 58.80 and 71.46 g with an increase over control by 76.76 and 67.97% of fresh flowers and 62.88 and 64.31% of dry flowers in the first and second seasons, respectively. Similar results were obtained by Salama *et al.* (2003) on fresh and dry weight of *Verbascum thapsus* flowers.

Yield of dry flowers/fed. of *Verbascum thapsus* as affected by NPK fertilization treatments followed a similar trend as that found with dry weight of flowers/plant as shown in Table (3). Since, the dry flowers yield/fed. of mullein recorded a significant increase by using the highest level of NPK fertilization ($N_3P_3K_3$) comparing to the other treatments or control in both seasons. This level produced 1.44 and 1.73 ton. of dry flowers/fed. with 65.52 and 66.35% increase over the control in the two seasons, respectively. Similar results were obtained by Salama *et al.* (2003) on common mullein regarding flower yield/plant and Roki *et al.* (2001) on *Arnica chamissonis*.

Effect of the interaction between plant spacings and NPK fertilization levels on some flowering parameters:

Data of both seasons in Table (3) pointed out that both of fresh and dry weights of *Verbascum thapsus* flowers/plant recorded a linear increase with increasing either plant spacing or NPK fertilization levels with significant differences in this respect comparing to plant spacing without NPK fertilization. Likewise, the heaviest weights of fresh flowers (638.46 and 615.11 g) and dry flowers (66.77 and 86.02 g) per plant were obtained from the combination between the widest spacing (40 cm) and the highest level of NPK fertilization ($N_3P_3K_3$) in the two seasons with significant differences in comparison with the other combinations under this study. However, the lowest weight of fresh and dry flowers/plant was produced by the narrowest spacing without fertilization.

As shown in Table (3) the reversal interaction between plant spacing and NPK fertilization levels led to an increase in the yield of flowers. Plant spacing at 20 cm and $N_3P_3K_3$ fertilization level significantly produced the highest yield of flowers as 1.79 and 2.02 ton/fed. in the first and second seasons, respectively.

Effect of plant spacings on some active ingredients in the dry leaves and flowers:

From data in Table (4), it is obvious that total iridoid glycosides (T.I.G) content, total saponins (T.S) and total mucilages (T.M) percentages in dry leaves and flowers were increased with increasing the spacing between plants. Likewise, significant increases were recorded in T.I.G content, T.S and T.M percentages as plant spacing was increased from 20 to 30 or 40 cm in the two seasons. In addition, the wide spacing (40 cm) gave the highest values of the three components as 67.72 and 71.42 mg/100g.d.w of T.I.G, 6.97 and 7.27% of T.S and 4.02 and 4.23% of T.M in the leaves and as 171.64 and 179.82 mg/100g.d.w of T.I.G, 28.98 and 31.96% of T.S and 3.41 and 3.44% of T.M in the flowers in the first and second seasons, respectively. Similar results regarding mucilages and saponins percentages in mullein leaves and flowers were reported by Mahmoud (1980).

The wider cultivation may permit more vegetative and root growth, consequently more nutrients absorption and/or accumulation than closer cultivation. This positive effects might increase the content of the active components like total iridoid glycosides, total saponins and total mucilages in the leaves and flowers.

Effect of NPK fertilization levels on some active ingredients in the dry leaves and flowers:

Data given in Table (4) clearly indicated that each of total iridoid glycosides (T.I.G) content, total saponins (T.S) and total mucilages (T.M) percentages of *Verbascum thapsus* leaves and flowers were significantly increased as NPK fertilization levels increased. In this respect, the highest level ($N_3P_3K_3$) significantly gave the highest values with an increase over the control as 64.85 and 62.67% of T.I.G, 36.07 and 33.39% of T.S and 51.22 and 52.68% of T.M in the leaves and as 40.0 and 37.70% in T.I.G, 48.61 and 58.95% in T.S and 67.92 and 68.18% in T.M in the flowers in the first and second seasons, respectively. The obtained results are in harmony with those reported by Nandi and Chatterjee (1991) on *Digitalis lanata* and *Digitalis purpurea* and Hammam (2002) on senna regarding glycosides content. Also with Salama *et al.* (2003), regarding the three components in the leaves and flowers of common mullein.

Effect of the interaction between plant spacings and NPK fertilization levels on some active ingredients in the dry leaves and flowers:

Data illustrated in Table (4) reveal that the interaction treatment between plant spacing at 40 cm and fertilization with $N_3P_3K_3$ level recorded the highest values of total iridoid glycosides content, total saponins and total mucilages percentages in dry leaves and flowers with significant differences as compared to the other interaction treatments or plant spacing alone without fertilization during the two seasons. Moreover, the contents of these components were significantly increased by increasing NPK fertilization and plant spacing levels under each level of the other factor. Generally, total iridoid glycosides content, total saponins and total mucilages percentages in both leaves and flowers were higher in the second season than in the first one.

From the obtained results it is recommended to cultivate the plants in rows at 20 cm spacing between the plants with application of the highest level of NPK fertilization ($N_3P_3K_3$) in order to maximize the yield of leaves and flowers of *Verbascum thapsus*, otherwise, it is suggested to increase the culture spacing between Verbascum plants into 40 cm to maintain quality of flowers and to make the harvesting process easier and faster with NPK fertilization at $N_3P_3K_3$ level (61.5, 46.5 and 72 kg of N, P_2O_5 and K_2O/fed., respectively).

Table (3): Effect of plant spacings, NPK fertilization levels and their interaction on some flowering parameters of *Verbascum thapsus* L. during seasons 2005-2006 and 2006-2007.

Treatments		First season			Second season		
Plant spacing	**NPK fertilization (kg/fed.)**	**Fresh weight of flowers/plant (g)**	**Dry weight of flowers/plant (g)**	**Yield of dry flowers/fed (ton)**	**Fresh weight of flowers/plant (g)**	**Dry weight of flowers/plant (g)**	**Yield of dry flowers/fed (ton)**
20 cm	$N_0P_0K_0$	230.65 ^{k}	30.08 ^{k}	1.05 ^{h}	253.39 ^{k}	34.55 ^{i}	1.21 ^{f}
	$N_1P_1K_1$	296.47 ^{i}	36.20 ^{i}	1.27 ^{d}	314.38 ^{i}	42.06 ^{h}	1.47 ^{cd}
	$N_2P_2K_2$	340.71 ^{h}	41.50 ^{h}	1.45 ^{b}	366.91 ^{h}	47.64 ^{g}	1.67 ^{b}
	$N_3P_3K_3$	405.67 ^{f}	51.23 ^{e}	1.79 ^{a}	439.75 ^{e}	57.69 ^{e}	2.02 ^{a}
30 cm	$N_0P_0K_0$	275.05 ^{j}	33.87 ^{j}	0.79 ^{j}	291.24 ^{j}	41.81 ^{h}	0.98 ^{h}
	$N_1P_1K_1$	360.27 ^{g}	47.03 ^{f}	1.10 ^{g}	421.57 ^{f}	53.45 ^{f}	1.24 ^{f}
	$N_2P_2K_2$	424.11 ^{e}	51.92 ^{e}	1.21 ^{e}	470.56 ^{d}	62.34 ^{d}	1.45 ^{de}
	$N_3P_3K_3$	493.47 ^{c}	58.41 ^{c}	1.36 ^{c}	514.57 ^{c}	70.67 ^{c}	1.65 ^{b}
40 cm	$N_0P_0K_0$	364.20 ^{g}	44.34 ^{g}	0.78 ^{j}	389.73 ^{g}	54.12 ^{f}	0.95 ^{h}
	$N_1P_1K_1$	455.17 ^{d}	56.49 ^{d}	0.99 ^{i}	500.41 ^{c}	63.62 ^{d}	1.11 ^{g}
	$N_2P_2K_2$	597.57 ^{b}	61.66 ^{b}	1.08 ^{gh}	562.53 ^{b}	80.47 ^{b}	1.41 ^{e}
	$N_3P_3K_3$	638.45 ^{a}	66.77 ^{a}	1.17 ^{f}	615.11 ^{a}	86.02 ^{a}	1.50 ^{c}
Main effect of plant spacing	20 cm	318.38 ^{c}	39.75 ^{c}	1.39 ^{a}	343.61 ^{c}	45.49 ^{c}	1.59 ^{a}
	30 cm	388.23 ^{b}	47.81 ^{b}	1.12 ^{b}	424.49 ^{b}	57.07 ^{b}	1.33 ^{b}
	40 cm	513.85 ^{a}	57.32 ^{a}	1.00 ^{c}	516.95 ^{a}	71.06 ^{a}	1.24 ^{c}
Main effect of NPK	$N_0P_0K_0$	289.97 ^{d}	36.10 ^{d}	0.87 ^{d}	311.45 ^{d}	43.49 ^{d}	1.04 ^{d}
	$N_1P_1K_1$	370.64 ^{c}	46.57 ^{c}	1.12 ^{c}	412.12 ^{c}	53.05 ^{c}	1.28 ^{c}
	$N_2P_2K_2$	454.13 ^{b}	51.69 ^{b}	1.25 ^{b}	466.67 ^{b}	63.48 ^{b}	1.51 ^{b}
	$N_3P_3K_3$	512.53 ^{a}	58.80 ^{a}	1.44 ^{a}	523.15 ^{a}	71.46 ^{a}	1.72 ^{a}

*Means in the same column with the same letters are not significantly different at $p < 0.05$ according to Duncan's multiple range test.

Table (4): Effect of plant spacings, NPK fertilization levels and their interaction on some active ingredients in the dry leaves and flowers of *Verbascum thapsus* L. during seasons 2005-2006 and 2006-2007.

Treatments		Dry leaves						Dry flowers					
		First season			Second season			First season			Second season		
Plant spacing	NPK fertilization (kg/fed.)	T.I.G. (mg/100g .d.w.)	T.S. (%)	T.M. (%)	T.I.G. (mg/100g .d.w.)	T.S. (%)	T.M. (%)	T.I.G. (mg/100g .d.w.)	T.S. (%)	T.M. (%)	T.I.G. (mg/100g .d.w.)	T.S. (%)	T.M. (%)
20 cm	$N_0P_0K_0$	44.56 ^{l}	4.68 ^{k}	2.53 ^{k}	44.88 ^{k}	5.08 ^{i}	2.60 ^{k}	119.58 ^{k}	18.55 ^{l}	2.20 ^{j}	128.59 ^{k}	20.54 ^{k}	2.20 ^{i}
	$N_1P_1K_1$	54.48 ^{i}	5.38 ^{j}	3.39 ^{h}	55.62 ^{h}	5.87 ^{k}	3.65 ^{h}	151.20 ^{h}	21.25 ^{j}	2.89 ^{g}	159.22 ^{h}	24.74 ^{h}	2.90 ^{g}
	$N_2P_2K_2$	62.82 ^{g}	6.35 ^{g}	3.82 ^{f}	68.14 ^{f}	6.63 ^{h}	3.97 ^{g}	171.51 ^{e}	24.43 ^{g}	3.57 ^{d}	178.89 ^{e}	28.74 ^{f}	3.60 ^{d}
	$N_3P_3K_3$	69.70 ^{e}	6.95 ^{e}	3.96 ^{e}	78.30 ^{c}	7.21 ^{e}	4.14 ^{f}	182.65 ^{c}	28.16 ^{d}	3.90 ^{b}	193.14 ^{b}	32.34 ^{c}	3.94 ^{b}
30 cm	$N_0P_0K_0$	47.51 ^{k}	5.78 ^{i}	2.90 ^{j}	53.16 ^{i}	6.02 ^{j}	3.02 ^{j}	137.60 ^{j}	20.80 ^{k}	2.45 ^{i}	147.92 ^{j}	21.39 ^{j}	2.49 ^{h}
	$N_1P_1K_1$	60.61 ^{h}	6.33 ^{g}	3.74 ^{g}	64.79 ^{g}	6.80 ^{g}	3.96 ^{g}	161.52 ^{g}	22.74 ^{h}	3.07 ^{f}	172.00 ^{g}	26.82 ^{g}	3.07 ^{f}
	$N_2P_2K_2$	72.04 ^{d}	7.04 ^{d}	4.13 ^{d}	73.14 ^{d}	7.31 ^{d}	4.36 ^{d}	179.22 ^{d}	26.28 ^{f}	3.72 ^{c}	184.78 ^{d}	31.42 ^{d}	3.74 ^{c}
	$N_3P_3K_3$	76.58 ^{b}	7.53 ^{b}	4.40 ^{b}	80.76 ^{b}	7.74 ^{b}	4.67 ^{b}	189.04 ^{b}	29.16 ^{c}	4.06 ^{a}	193.96 ^{b}	35.34 ^{b}	4.11 ^{a}
40 cm	$N_0P_0K_0$	48.25 ^{j}	6.02 ^{h}	3.23 ^{i}	52.41 ^{j}	6.25 ^{i}	3.33 ^{i}	146.61 ^{i}	22.29 ^{i}	2.54 ^{h}	151.53 ^{i}	24.28 ^{i}	2.56 ^{h}
	$N_1P_1K_1$	63.97 ^{f}	6.55 ^{f}	3.87 ^{f}	69.78 ^{e}	7.01 ^{f}	4.23 ^{e}	163.32 ^{f}	26.63 ^{e}	3.23 ^{e}	174.93 ^{f}	30.79 ^{e}	3.26 ^{e}
	$N_2P_2K_2$	73.64 ^{c}	7.40 ^{c}	4.34 ^{c}	77.81 ^{c}	7.61 ^{c}	4.53 ^{c}	182.98 ^{c}	32.69 ^{b}	3.70 ^{c}	190.52 ^{c}	35.21 ^{b}	3.79 ^{c}
	$N_3P_3K_3$	85.02 ^{a}	7.92 ^{a}	4.66 ^{a}	85.67 ^{a}	8.20 ^{a}	4.84 ^{a}	193.63 ^{a}	34.29 ^{a}	4.13 ^{a}	202.31 ^{a}	37.56 ^{a}	4.16 ^{a}
Main effect of plant spacing	20 cm	57.89 ^{c}	5.84 ^{c}	3.42 ^{c}	61.74 ^{c}	6.20 ^{c}	3.59 ^{c}	156.24 ^{c}	23.10 ^{c}	3.14 ^{c}	164.96 ^{c}	26.59 ^{c}	3.16 ^{c}
	30 cm	64.18 ^{b}	6.67 ^{b}	3.79 ^{b}	67.96 ^{b}	6.97 ^{b}	4.00 ^{b}	166.84 ^{b}	24.75 ^{b}	3.33 ^{b}	174.67 ^{b}	28.74 ^{b}	3.36 ^{b}
	40 cm	67.72 ^{a}	6.97 ^{a}	4.02 ^{a}	71.42 ^{a}	7.27 ^{a}	4.23 ^{a}	171.64 ^{a}	28.98 ^{a}	3.40 ^{a}	179.82 ^{a}	31.96 ^{a}	3.44 ^{a}
Main effect of NPK	$N_0P_0K_0$	46.77 ^{d}	5.49 ^{d}	2.89 ^{d}	50.15 ^{d}	5.78 ^{d}	2.98 ^{d}	134.60 ^{d}	20.55 ^{d}	2.40 ^{d}	142.68 ^{d}	22.07 ^{d}	2.42 ^{d}
	$N_1P_1K_1$	59.69 ^{c}	6.08 ^{c}	3.67 ^{c}	63.40 ^{c}	6.56 ^{c}	3.95 ^{c}	158.68 ^{c}	23.54 ^{c}	3.06 ^{c}	168.72 ^{c}	27.45 ^{c}	3.08 ^{c}
	$N_2P_2K_2$	69.50 ^{b}	6.93 ^{b}	4.09 ^{b}	73.03 ^{b}	7.18 ^{b}	4.29 ^{b}	177.90 ^{b}	27.80 ^{b}	3.66 ^{b}	184.73 ^{b}	31.79 ^{b}	3.71 ^{b}
	$N_3P_3K_3$	77.10 ^{a}	7.47 ^{a}	4.34 ^{a}	81.58 ^{a}	7.71 ^{a}	4.55 ^{a}	188.44 ^{a}	30.54 ^{a}	4.03 ^{a}	196.47 ^{a}	35.08 ^{a}	4.07 ^{a}

*Means in the same column with the same letters are not significantly different at $p < 0.05$ according to Duncan's multiple range test.
*T.I.G = total iridoid glycosides, T.S = total saponins and T.M = total mucilages.

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تأثير مسافات الزراعة و مستويات التسميد الكيماوى و التفاعل بينهما علي النمو الخضرى والزهرى وبعض المواد الفعالة لنبات الفرباسكم (آذان الدُب) تحت ظروف الأراضى الرملية

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تم إجراء هذا البحث فى المزرعة البحثية لمحطة بحوث البساتين بالقصاصين، محافظة الإسماعيلية، مصر خلال موسمي ٢٠٠٥- ٢٠٠٦ و ٢٠٠٦- ٢٠٠٧ بهدف دراسة التأثيرات المختلفة لمسافات الزراعة و مستويات التسميد الكيماوى (النيتروجين و الفوسفور و البوتاسيوم) بالإضافة إلى التفاعل بينهما على النمو الخضري والإزهار و بعض المواد الفعالة لنباتات الفرباسكم (آذان الدُب) النامية تحت ظروف الأراضى الرملية. وقد تم استخدام ثلاث مسافات زراعة بين النباتات داخل الخط هى ٢٠ و٣٠ و ٤٠ سم وأربعة مستويات من التسميد الكيماوى (NPK) هى (صفر : صفر : صفر) و (٢٠,٥ : ١٥,٥ :٢٤) و (٤١ : ٣١ : ٤٨) و (٥, ٦١ : ٤٦,٥ : ٧٢) كجم/فدان من N : P_2O_5 : K_2O على التوالى. و تم أخذ النتائج عن النمو و محصول الأوراق والأزهار الجافة وكذلك تقدير بعض المواد الفعالة فى أوراق و أزهار الفرباسكم. و قد أوضحت النتائج أن أعلى إنتاجية من الأوراق والأزهار الجافة وكذلك أعلى محتوى من المواد الفعالة فى الأوراق والأزهار (الجليكوسيدات الايريدويدية و السابونينات والمواد المخاطية) للنبات تم الحصول عليها باستخدام المستويات الأعلى من كل من مسافات الزراعة (٤٠ سم) والتسميد الكيماوى (٦١,٥ : ٤٦,٥ : ٧٢ كجم/فدان) منفردة أو بالتفاعل بينهما. فى حين أن أعلى محصول من الأوراق والأزهار الجافة وكذلك المواد الفعالة للفدان تم الحصول عليها عند الزراعة على المسافة الضيقة (٢٠ سم) أو المستوى الأعلى من التسميد الكيماوى أو تفاعلهما معاً فى كلا الموسمين.