Assessment of Nitrogen Levels on Flower yield of Calendula Grown under Different Water deficit Stresses Using Drough Tolerant Indices

Tofigh Taherkhani[1*], Navid Rahmani[1], Amin Moradi Aghdam[1]and Peiman Zandi[2]
[1]Young Researchers Club, Takestan Branch, Islamic Azad University, Takestan, Iran
[2]Department of Agronomy, Takestan Branch, Islamic Azad University, Takestan, Iran
tofightaherkhani@yahoo.com; amin.moradi.aghdam@gmail.com;
z_rice_b@yahoo.com

Abstract: To understand the impact of water deficit stress and nitrogen application on the calendula flower yield, the experiment was laid out as a randomized complete block design with split-plot arrangement. Soil-water regimes consisted of three levels (irrigation after 40-normal stress, 80-mild stress, and 120-severe stress mm evaporation from class 'A' pan) which allotted to the main plots and Nitrogen rates including 0, 30, 60, and 90 kg n/ha were assigned to subplots. Six drought resistant indices include mean productivity (MP), geometric mean productivity(GMP), stress tolerance index(TOL), susceptible stress index(SSI), stress tolerance index(STI) and harmonic mean(Harm) were applied on the basis of flower yield in normal, mild and sever stress condition. Evaluation of different nitrogen application rates by the means of drought tolerant indices asserted that, the highest flower yield under mild/severe stress was achieved via treatments which received 90 kg n/ha . 3D scatter plot results were also cleared the superiority of the same rank of nitrogen application as the best level. Correlation coefficients between indices and yield under stress /non-stress conditions showed that GMP, STI, MP, Harm and TOL under mild stress, in addition SSI, Harm, GMP, STI, MP and TOL under severe stress were the most effective level identifying indices

[Tofigh Taherkhani, Navid Rahmani, Amin Moradi Aghdam, Peiman Zandi. **Assessment of Nitrogen Levels on Flower yield of Calendula Grown under Different Water deficit Stress Using Drough Tolerant Indices**. Journal of American Science 2011; 7(10):591-598]. (ISSN: 1545-1003). http://www.americanscience.org

Keywords: *Calendula officinalis L.*, water deficit stress, nitrogen fertilizer, tolerance indices, flower yield.

Abbreviations: SSI_ stress susceptibility index, STI_ stress tolerance index, TOL_ stress tolerance, MP_ mean productivity, GMP_ geometric mean productivity, Ys_ flower yield under drought condition, Yp_ flower yield under normal condition.

1. Introduction

Drought is one of the main limiting factors of plant growth throughout the world and is the most common environmental stress, which has limited almost 25% of the world's agricultural lands. In spite of the extensive and comprehensive researches that have been conducted on the effect of water stress on agricultural products, the behavior of medicinal plants in such conditions has not been studied adequately (Fageria,1992). Nitrogen is among elements, whose deficiency in arid and semi-arid regions is considerable because the amount of organic matters, which are the main nitrogen reserves, is very low in these regions and even if they are found, they would be quickly decomposed (Mangel,1992). In cases where the available nitrogen is less or more than a plant's requirement, it can cause disorders in the plant's vital processes, which might appear differently as too much growth and development, reduced transpiration or even stunted reproductive growth (Breemhaar and Bouman**,** 1995). Evergreen (*Calendula officinalis L.*) is an herbaceous, annual and rarely biennial plant with a tightly branched stem. It has a rapid growth and development in a way that 40-50 days after emergence, it starts flowering. In Iran, it's blooming starts in late May, which continues until the beginning of the cold season and lasts for 70-120 days. The seed of this plant is in the form of achene, whose size decreases from the end to the center and its 1000-seed weight is 10-15 g (Omid beigi, 2005). Since the production of secondary metabolites in plants changes by environmental factors and that water stress is also an effective factor in the growth and synthesis of natural compounds of medicinal herbs, presenting methods which can produce a plant with more active substances seems necessary (Baher et al ., 2002). Jangir and Singh (1996) studied the effect of 4, 5 and 6 irrigation times on the cumin (*Cuminum cymimum*) yield. Their results showed that the irrigation regime had a significant effect on the seed yield and its attributes and that 5 times of irrigation increased the yield compared with that of the 4 times of irrigation. However, more irrigation (6 times) did not increase the yield. In the experiments conducted by Babakhanlou et al. (2001) on fennel (*Foeniculum vulgare*), using chemical fertilizers not only increased the seed yield, but also increased the essence production rate. Regarding Moldavian dragonhead (*Dracocephalum moldavica*), application of nitrogen fertilizer during different growth stages resulted in the increased number of lateral branches, early flowering, increased length of top-flowered branches, 1000-seed weight and the germination percentage which compared with controls, there was a significant difference

(Safikhani et al., 2007). In their studies on *Calendula officinalis*, Arganosa et al. (1998) applied 0, 20, 40, 60, 80 and 100 kg/ha nitrogen and found that the highest biological yield and the seed yield were obtained from applying 80 kg n/ha. In this regard, similar results were obtained in experiments conducted by Alizadeh Sahzabi et al. (2007) on *Satureja hortensis*, and Abbaszadeh et al. (2007) on lemon balm (*Melissa officianlis*). In their studies on the evergreen plant, Shubhra et al. (2004) found that the height and the number of flowers per plant excessively decreased under drought stress conditions. Rahmani et al. (2008) reported that the highest flower yield was obtained from 40 mm evaporation from Class A evaporation pan (circular pan), while the highest extract percentage was obtained from 80 mm evaporation from the said pan. In fact, drought stress activates morphological, physiological and metabolic processes and increases a plant's ability to confront water deficit. Many of these reactions, especially the physiological and metabolic ones are of the endothermic type. Regulating the application of nitrogen under water deficit conditions, due to its effect on the vegetative development and metabolic processes of a plant is of great importance.

With consideration of what has been mentioned so far, the main objectives of the present research was to study and choose the best drought tolerance index and the most suitable nitrogen application level that causes the highest flower yield of the calendula in both stressed and non-stressed environments.

2. Materials and Methods

2.1Site of Experiment

This study was undertaken at the research farm of the Islamic Azad University (Takestan branch) during growing season of 2006(April-July). The site is located at latitude of 36°04' N, longitude of 49°39'E and 1283.4 m above the sea level with mean annual precipitation of 252.6 mm. It should be said that the mean temperature in Takestan during the last 10 years (1997-2006) before the experiment was 28 °C and -2 °C in the hottest and coldest months of a year, respectively. The soil texture was Sandy- loam with pH=7.7 and EC 0.521 ds/m (Table 1).

Table1. Physical and chemical properties of experimental soil before planting

O.C (%)	N (%)	P (ppm)	K (ppm)	EC (ds/m)	pH	Texture			S.P (%)
						Sand (%)	Silt (%)	Clay (%)	
0.29	0.02	6.6	287	0.521	7.7	60	19	21	6.2

2.2Plant materials and Drought / Nitrogen treatments

The experiment was laid out based on split plots in a randomized complete block design with four replications. Evaluated treatments included water deficit stress at three levels (40, 80 and 120 mm evaporation from Class 'A' pan) in main plots and nitrogen application at four levels (0, 30, 60 and 90 kg /ha) in the form of urea randomized in sub-plots. Regulating the irrigation time at stress levels was done using the Class 'A' evaporation pan at the university's weather station. Due to cold weather, rainfall, hail and sleet during the early season in the region, sowing was done in mid April. Each plot was 6 meters length and 3.6 meters width. The ridges were 0.6 meters apart and there were 6 planting rows in each plot. The method used here was mass sowing of two rows per bed/ridge, 3-4 seeds per place, 2-3 cm deep with 12 cm of in-row spacing (28 plants per m^2). In order to prevent the penetration of water to adjacent plots, the distance between blocks was 4 meters. After the emergence of seedlings at the soil surface, thinning was done at the 4-5 true leaf stage. Before implementing the stress treatment, irrigation was done, with consideration of the soil tissue and weather conditions, in the form of flood irrigation once every 5 days. The irrigation treatment was implemented after the seedlings were established 30-40 days after sowing (DOS) and before the reproductive growth. Nitrogen was applied in two stages, half of it after the emergence stage and half before flowering in the form of strips between the sowing rows. The studied trait was the flower yield. Measurement was done in different stages including 50% and 100% of flowering. All samplings were done at 2 m^2 of each plot by taking the effect of margins into account/after discarding the margins. The Heads were weighed using a 0.001g precision scale. *Drought indices* In order to study the reaction of different nitrogen levels to drought stress, different indices were calculated using the following relationships:

(Fischer and Mourer, 1987) (1)

$$\text{Stress Susceptibility Index (SSI)} = \frac{1-\left(\frac{Y_S}{Y_P}\right)}{SI}$$

(Fischer and Mourer, 1987) (2)

$$\text{Stress Intensity (SI)} = 1-\left(\frac{\bar{Y}_S}{\bar{Y}_P}\right)$$

(3)

$$\text{Harmonic Mean (Harm)} = \frac{2(\text{Yp} \times \text{Ys})}{\text{Yp} + \text{Ys}}$$

Note. The higher this index, the more desirable

(Rosille and Hambilin, 1981) (4)

$$\text{Tolerance Index (TOL)} = Y_P - Y_S$$

Note. Yield differences in stress and non-stress environments.

(Rosille and Hambilin, 1981) (5)

$$\text{Mean Productivity (MP)} = \frac{Y_P + Y_S}{2}$$

Note. Mean yield in stress and non-stress environments, more tolerant and desirable levels have higher MPs.

(Fernandez, 1992) (6)

$$\text{Stress Tolerance Index (STI)} = \frac{Y_P \times Y_S}{\bar{Y}_P^2}$$

Note. Higher values of STI for different levels are indicators of high levels of drought tolerance and a higher potential yield of that level.

(Fernandez, 1992) (7)

$$\text{(GMP)} = \sqrt{Y_P \times Y_S}$$

Note. This index (Geometric Mean Productivity) is less sensitive to very different *Ys* and *Yp* values and its value is an indication of its being more tolerant of stress.

Where, *Yp* is the potential yield of each nitrogen level under no-stress environment, *Ys*, the potential yield of each nitrogen level under stress environment, $\bar{Y}p$ and $\bar{Y}s$ are the mean yields of all nitrogen levels under stress and non-stress environment, respectively. Among the stress tolerance indices, a larger value of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favorable. In addition, selection based on STI and GMP will be resulted in cultivars with higher stress tolerance and yield potential will be selected (Fernandez, 1992).

2.3 Selection criteria and Statistical analysis

Correlations between tolerance indices, *Yp* and *Ys* were computed under stress and non-stress conditions and considering the correlation between these indices and the yield, and also by taking the ranking results of different nitrogen application rates in stress /non-stress conditions into account, the most suitable drought tolerance indices were selected. Then, based on the selected indices, the most tolerant levels of nitrogen (n) in both environments were identified using a 3-dimensional display by means of Statistica software and for analyzing the data, SPSS ver. 15 software was used.

3. Results & Discussion

3.1 Mild stress condition

For the Mean Productivity index (MP), whose high value is an indication of the relative stress tolerance, nitrogen levels of 90 and 60 kg/ha (MP_{90}= 1888.31 and MP_{60}= 1748.25) under mild stress conditions were selected as the most tolerant levels with high flower yields (Table 3). In addition, 3D scatter plot results of Y_p, Y_s and MP (Figure 1) showed that nitrogen application levels of 3 and 4 in region A, i.e. the region with high Y_p, Y_s and MP values, were selected as the most tolerant levels. Rating results of different nitrogen application levels in terms of MP under mild stress conditions selected level 4 as the first order or the most desirable level as well (Table 3). As seen in the correlation table, there was a highly significant correlation between MP and Y_p, Y_s, TOL, GMP, Harm and STI (Table 2). Since a suitable index for selection is that it would lead to the selection of high yield levels under stressed and non-stressed conditions, MP was recognized as a suitable index for identifying drought tolerance levels.

Regarding the Mean Harmonic index (Harm), of the four different nitrogen application levels and their effects on the flower yield, levels 4 and 3 with $Harm_{90}$= 1548.06 and $Harm_{60}$= 1444.27 were selected as the most desirable levels of drought stress tolerance (Table 3). In addition, 3D scatter plot results of Y_p, Y_s and Harm selected the mentioned two levels as the most tolerant ones (Figure 2). Ranking results of different nitrogen application levels for Harm index selected level 4 as the first order or the most desirable level under mild stress conditions (Table 3). It should be noted that high values of this index are indicators of relative tolerance to drought. According to correlation results, there was a high and significant difference between this index (Harm) and Y_p, Y_s, TOL, GMP, MP and STI (Table 2). Due to the selection of nitrogen levels, which have high yields under stress and non-stress conditions, it was recognized as another suitable index.

In terms of Stress Tolerance Index (STI), whose high values indicate a relative stress tolerance, level 4 of nitrogen application with a value of 0.506 under mild stress conditions was selected as the most tolerant (Table 3). Based on ranking results of different nitrogen application levels regarding STI, under said conditions (mild stress), n_4 selected as the first order or the most desirable level (Table 3). Furthermore, 3D scatter plot results of Y_p, Y_s, and STI showed that nitrogen application levels of 60 and 90 kg/ha were identified as levels with high flower yields under stressed and non-stressed conditions (Figure 3). As shown in Table 2, there was highly significant correlation between this index (STI) and Y_p, Y_s, TOL, GMP, Harm and MP and that it was selected as a suitable index for identifying different desirable levels.

Regarding stress susceptibility index (SSI), whose low values are indicators of Tolerance, 90 kg/ha of nitrogen application level was selected as the best level with a value of 0.99 (Table 3). Also, 3D scatter plot results of Y_p, Y_s, and SSI showed that 60 and 90 kg n/ha were selected in region A, which had low SSI values and high yields under stress and non-stress conditions (Figure 4). Rating results of different nitrogen levels in terms of SSI under mild stress conditions introduced levels 4 and 1 as the most desirable and the least suitable nitrogen application levels, respectively (Table 3). However, this level (4) had a high SSI value. There was a negative correlation between SSI and the other indices (Table 2). Since a suitable index is an index, which leads to selecting levels of nitrogen application with high yields under stress and non-stress conditions, the said index was not identified as a suitable one.

Concerning the Tolerance Index (TOL), its low values are indicators of a relative tolerance of nitrogen levels. Under mild stress conditions, level 4 of nitrogen application was selected as the most tolerant level with a value of 1603.13 (Table 3). Moreover, scatter plot results of Y_p, Y_s, and TOL also showed that 60 and 90 kg n/ha, which had low TOL values, were selected. In region 'A', n_3 and n_4 were selected for their high yields under stress and non-stress conditions (Figure 5).

Concerning the TOL index under mild stress conditions, ranking results of different nitrogen application levels selected levels 4 and 1 as the most desirable and the least suitable levels (Table 3). Correlation coefficients results indicated that, there was a significant correlation between TOL and Y_p, Y_s, MP, GMP, Harm and STI (Table 2). Since this index did not lead to the selection of levels of nitrogen application with high yields under stress and non-stress conditions, it was not identified as a suitable index.

Geometric Mean Productivity index (GMP), whose high values are tolerance indicators, n_4 with a value of 1709.74 was selected as the best level (Table 3). 3D scatter plot results of Y_p, Y_s, and GMP revealed that 60 and 90 kg n/ha, were selected as levels with high flower yields under stress and non-stress conditions (Figure 6). Although, rating results of different nitrogen levels for the GMP index under mild stress conditions introduced level 4 as the best level of nitrogen application (Table 3). As seen in the correlation table, there is a high and significant correlation between GMP and Y_p, Y_s, TOL, MP, Harm and STI (Table 2). Likewise, due to the selection of levels with high Y_p and Y_s values, it was selected as a suitable index.

Table 2. Correlation coefficients between Flower yield performance under normal irrigation (*Yp*), Flower yield performance under mild stress (*Ys*80) and drought tolerance/ susceptibility indices of studied *Calendula officinalis*

	Yp	*Ys*80	TOL	MP	GMP	Harm	SSI	STI
Yp	1	0.99**	0.99**	0.99 **	0.99**	0.99*	-0.74 ns	0.99**
*Ys*80		1	0.97*	0.99*	0.99**	0.99 **	-0.82 ns	0.99 **
TOL			1	0.98**	0.98**	0.97*	-0.66 ns	0.98**
MP				1	0.99 **	0.99**	-0.77 ns	0.99**
GMP					1	0.99 **	-0.77 ns	0.99**
Harm						1	-0.78 ns	0.99**
SSI							1	-0.77ns
STI								1

*, **significant at 5 and 1% of probability level, respectively; ns: not significant. TOL: tolerance index; MP: mean productivity; GMP: geometric mean productivity; Harm: harmonic mean; SSI: stress susceptibility index; STI: Stress tolerance index.

Table 3. Estimation of drought tolerance /susceptibility indices from the potential yield (*Yp*) and the mild stress yield (*Ys*80) data for different nitrogen levels along with Ranking results

[1]N	[2]*Yp* (kg/ha)	[3]*Ys* 80(kg/ha)	TOL	MP	GMP	Harm	SSI	STI	[4]MR
n_1	2158.65[4]	844.43[4]	1314.23[1]	1501.54[4]	1350.11[4]	1213.97[4]	1.016673[1]	0.316071[4]	3
n_2	2280.15[3]	903.15[3]	1377.00[2]	1591.65[3]	1435.03[3]	1293.83[3]	1.008473[2]	0.357079[3]	2.6
n_3	2477.25[2]	1019.25[2]	1458.00[3]	1748.25[2]	1589.00[2]	1444.27[2]	0.982837[3]	0.437817[2]	2.3
n_4	2689.88[1]	1086.75[1]	1603.13[4]	1888.31[1]	1709.74[1]	1548.06[1]	0.995243[4]	0.506878[1]	2

Note. [1]N: Nitrogen levels; [2]*Yp*: Flower yield performance under normal condition (40 mm evaporation from 'class A' pan); [3]*Ys* 80: Flower yield performance under mild stress condition (80 mm evaporation from 'class A' pan); [4]MR: Mean Rank

3.2 Severe stress condition

Regarding MP, whose high values under severe stress conditions indicate a relative stress tolerance, 90 kg/ha of nitrogen application level, i.e. the level 4 with a MP value of 1775.25 under the said conditions was selected as the most tolerant level with a high flower yield (Table 5). The results of Figure 7 showed that nitrogen application levels of n_3 and n_4 in region A, i.e. the region with high Y_p, Y_s, and MP values were selected as the most tolerant levels. Rating results of different nitrogen application levels base on MP under severe stress conditions selected level 4 as the first order or the most desirable level as well (Table 5). As seen in the correlation table, there was a high and significant correlation between MP and Y_p, Y_s, TOL, GMP, Harm, SSI and STI (Table 4). MP was determined as a suitable index for identifying drought tolerance levels, because under stress and non-stress conditions, it would lead to the selection of nitrogen application levels with high yields.

According to Harm index, the four different nitrogen levels and their effects on the flower yield, level 4 with a value of 1304.03 was selected as the most desirable level in terms of severe stress tolerance (Table 5). Also, 3D scatter plot results of Y_p, Y_s, and Harm selected n_3 and n_4 as the most tolerant levels (Figure 8). Rating results of different n levels for Harm index under severe stress conditions selected level 4 as the first order or the most desirable level (Table 5). It should be explained that high values of this index indicate a relative drought tolerance. The results of Table 4 showed that there was a high and significant correlation between Harm and Y_p, Y_s, as well as the rest of studied indices and due to the selection of nitrogen application levels, which have high yields under stress and non-stress conditions, it was identified as another suitable index.

For STI, level 4 of nitrogen application with a value of 0.40 under severe stress conditions was selected as the most tolerant level (Table 5).

Table 4. Correlation coefficients between Flower yield performance under normal irrigation (*Yp*), Flower yield performance under severe stress (*Ys*120) and drought tolerance/ susceptibility indices of studied *Calendula officinalis*

	Yp	*Ys*120	TOL	MP	GMP	Harm	SSI	STI
Yp	1	0.99**	0.99**	1.00 **	0.99**	0.99**	0.99**	0.99**
*Ys*120		1	0.99**	0.99 **	0.99**	0.99**	0.99**	0.99**
TOL			1	0.99 **	0.99**	0.99**	0.99**	0.99**
MP				1	0.99 **	0.99**	0.99**	0.99**
GMP					1	0.99 **	0.99**	0.99**
Harm						1	0.99 **	0.99**
SSI							1	0.99**
STI								1

*, **significant at 5 and 1% of probability level, respectively. TOL: tolerance index; MP: mean productivity; GMP: geometric mean productivity; Harm: harmonic mean; SSI: stress susceptibility index; STI: Stress tolerance index.

Table 5. Estimation of drought tolerance /susceptibility indices from the potential yield (*Yp*) and the severe stress yield (*Ys*120) data for different nitrogen levels along with Ranking results

[1]N	[2]*Yp* (kg/ha)	[3]*Ys* 120(kg/ha)	TOL	MP	GMP	Harm	SSI	STI	[4]MR
n_1	2158.65[4]	730.35[4]	1428.30[1]	1444.50[4]	1255.61[4]	1091.43[4]	0.986396[1]	0.273373[4]	3
n_2	2280.15[3]	762.07[3]	1518.08[2]	1521.11[3]	1318.19[3]	1142.35[3]	0.99253 [2]	0.301302[3]	2.6
n_3	2477.25[2]	809.33[2]	1667.92[3]	1643.29[2]	1415.94[2]	1220.05[2]	1.003739[3]	0.347644[2]	2.3
n_4	2689.88[1]	860.63[1]	1829.25[4]	1775.25[1]	1521.50[1]	1304.03[1]	1.013806[4]	0.40141[1]	2

Note. [1]N: Nitrogen levels; [2]*Yp*: Flower yield performance under normal condition (40 mm evaporation from 'class A' pan); [3]*Ys* 120: Flower yield performance under severe stress condition (120 mm evaporation from 'class A' pan); MR: Mean Rank

Ranking results of different nitrogen levels for STI under severe stress conditions selected level 4 as the first order or the most desirable level (Table 5). 3D scatter plot results of Y_p, Y_s, and STI also revealed that 60 and 90 kg/ha of nitrogen application levels were identified as levels with high flower yields under stress and non-stress conditions (Figure 9). Results of Table 4 emphasized that, there was a high and significant correlation between STI and Y_p, Y_s, TOL, GMP, Harm, SSI and MP indices; thus, it was selected as a suitable index for identifying desirable levels.

According to SSI, whose low values are indicators of tolerance, n_4 was selected as the best level with a value of 1.013806 (Table 5). Moreover, 3D scatter plot results of Y_p, Y_s, and SSI showed that 60 and 90 kg n/ha, with low SSI values were placed in region A with a high yield under stress and non-stress conditions (Figure 10). Rating results of different nitrogen application levels in terms of SSI under severe stress conditions introduced n_4 and n_1 as the most desirable and the least suitable levels of nitrogen application (Table 5). Correlation coefficient results showed that, SSI had positive significant correlation at 1% probability level with Y_p, Y_s, TOL, GMP, Harm, SSI, MP and STI (Table 4).

Under severe stress conditions, level 1 of nitrogen application with a value of 1428.30 was selected via TOL as the most tolerant level (Table

5). Furthermore, 3D scatter plot results of Y_p, Y_s, and TOL showed that 60 and 90 kg n/ha, which have low TOL values and high yields under stress and non-stress conditions were placed in region A (Figure 11). Rating results of different nitrogen application levels in terms of TOL under severe stress conditions introduced levels 4 and 1 as the most desirable and the least suitable levels, respectively (Table 5). As shown in Table 4, there was a high correlation between TOL and Y_p, Y_s, MP, GMP, Harm, SSI and STI. According to the above-mentioned reasons, this index was identified as a suitable index as well.

Finally, n_4 with a value of 1521.50 was selected via GMP, as the best level (Table 5). 3D scatter plot results of Y_p, Y_s, and GMP showed that 60 and 90 kg n/ha were identified as levels with high flower yields under stress and non-stress conditions (Figure 12). In addition, ranking results of different nitrogen levels in terms of GMP under severe stress conditions introduced level 4 as the best nitrogen application level (Table 5). It should be stated that there was a highly significant correlation between this index and Yp, Y_s, TOL, MP, Harm, SSI, and STI (Table 4). Due to the fact that this index could indentify levels with high Y_p and Y_s values, it was selected as a suitable index.

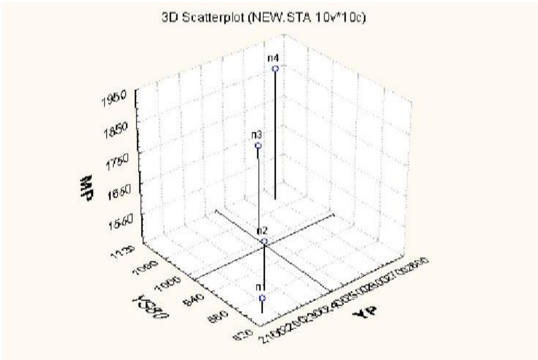

Fig.1

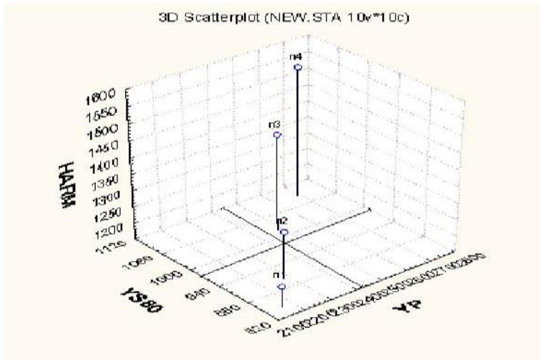

Fig.2

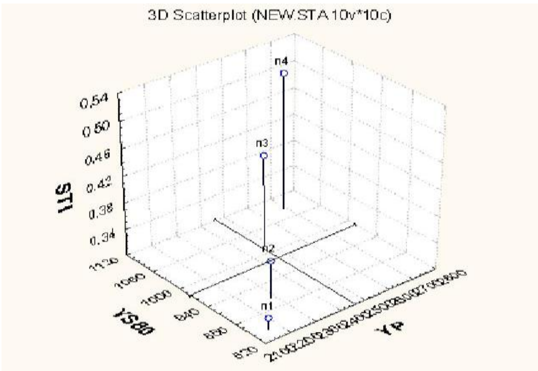

Fig.3

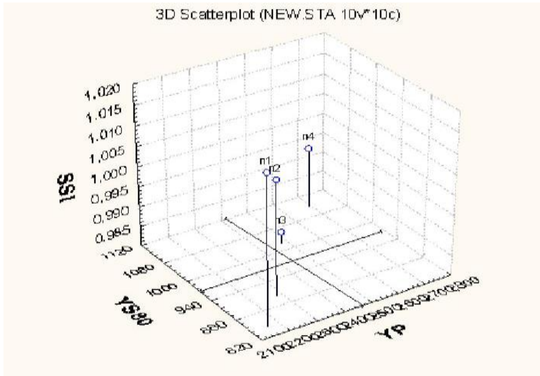

Fig.4

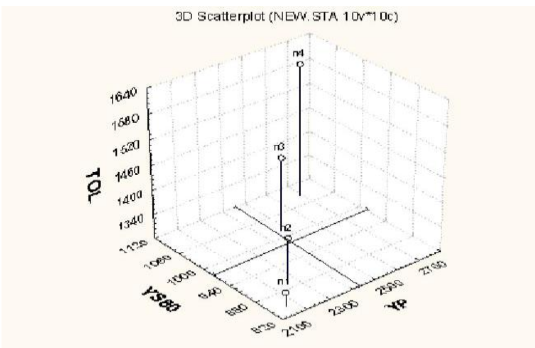

Fig.5

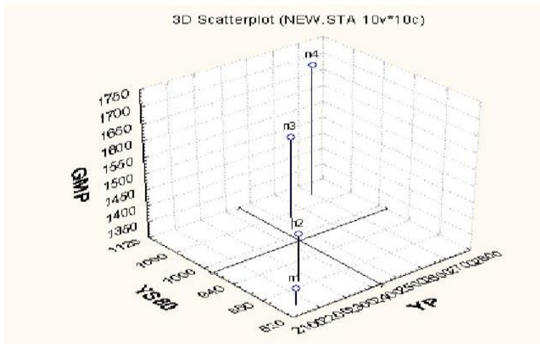

Fig.6

Figure 1-6. 3D scatter plot of identifying drought tolerant levels concerning MP, Harm, STI, SSI, TOL and GMP indices under mild stress condition

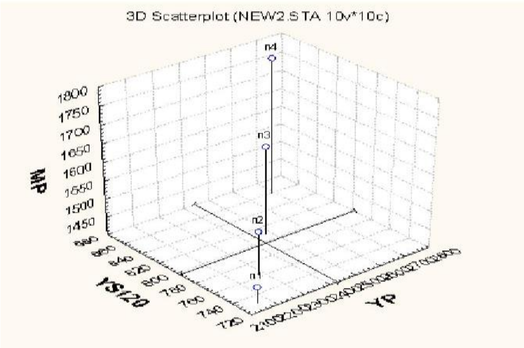

Fig.7

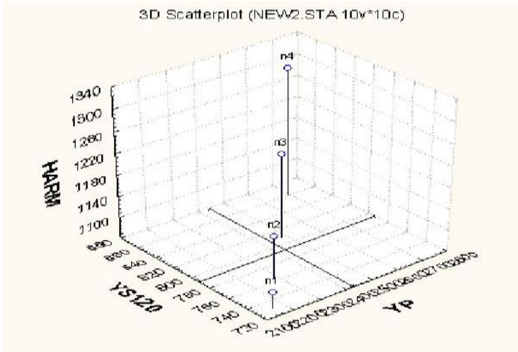

Fig.8

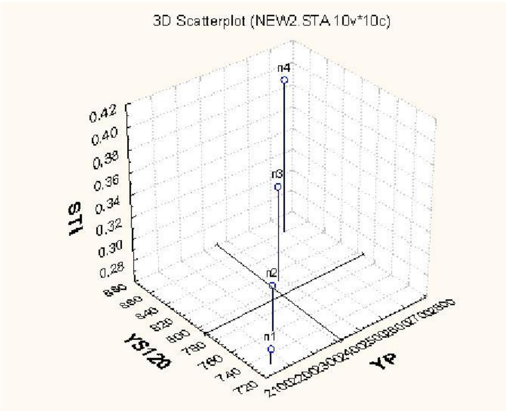

Fig.9

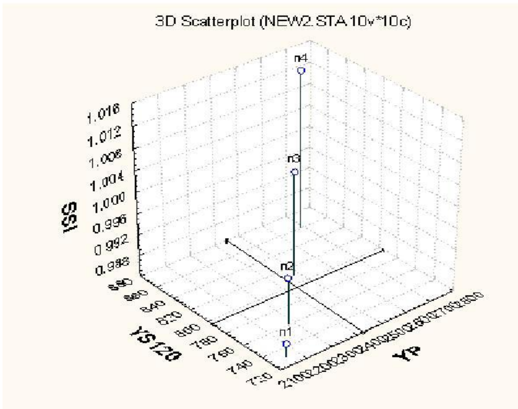

Fig.10

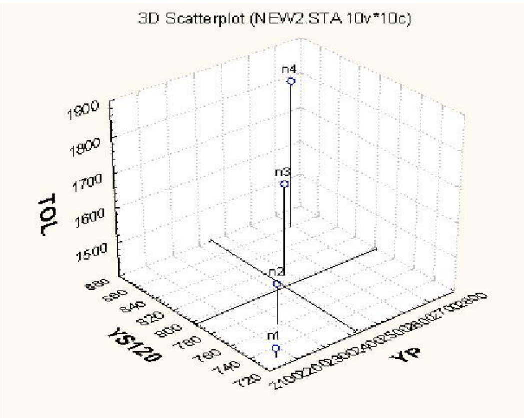

Fig.11

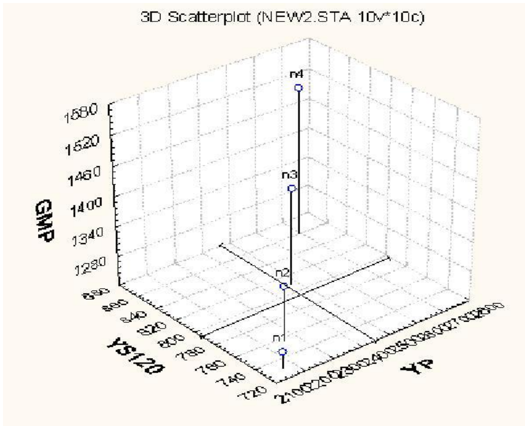

Fig.12

Figure 7-12. 3D scatter plot of identifying drought tolerant levels concerning MP, Harm, STI, SSI, TOL and GMP indices under severe stress condition

Conclusions

The salient findings of the investigation are summarized:

Applications of 90 kg n/ ha in both stress levels (mild /severe) was considered as a superior level and in comparison with other levels, resulted in higher yields. SSI, TOL, Harm, GMP, MP and STI, identified as a suitable indices in terms of their ability for recognizing desirable levels of nitrogen application under severe stress environment. TOL, Harm, GMP, MP and STI recognized as a suitable indices under mild stress environment. It was also showed that only TOL, Harm, GMP, MP and STI indices had high correlation with yield under mild and severe stress condition equally and were recognized as optimum indices for indentifying nitrogen level with high production and low sensitivity to drought stress.

Acknowledgements

The authors would like to appreciate the Research board of Takestan Azad University for financial support.

References

[1] Abbaszadeh, B., Sharifi Ashorabadi, E., Ardakani, M.R. and Aliabadi Farahani, H., 2007. Effect of Nitrogen Fertilizer on qualitative and qualitative yield of Balm (*Melissa officinalis* L.). In the Proceedings of the 1st National Congress of Ecological Agriculture. Gorgan University of Agricultural Sciences and Natural Resources, Iran, p. 61.

[2] Alizadeh Sahzabi, A., Sharifi Ashorabadi, E., Shirani Rad, A.H., Bigdeli, M. and Abbaszadeh, B., 2007. The effects of different methods and levels of using nitrogen on some quality and quantity characteristics of *Satureja hortensis* L. Iranian Journal of Medicinal and Aromatic Plants. 23(3), 416-431.

[3] Arganosa, G.C., Sosulski, F.W. and Slikard, A.E., 1998. Effect of nitrogen levels and harvesting management on quality of oil in *Calendula officinalis*. Indian Perfumer, 33(3), 182-195.

[4] Babakhanlou, P., Sefidkon, F., Sharifi Ashorabadi, E., Ghalavand, A., Amin, Gh. R., Noormohammadi, Gh. and Lebaschy, M.H., 2001. Effect of fertilization and manure on seed yield and biomass of Fennel. Iranian Journal of Medicinal and Aromatic Plant Res., 7 (0), 25-26.

[5] Baher, Z.F., Mirza, M., Ghorbani, M. and Rezaii, M.B., 2002. The influence of water stress on plant height, herbal and essential oil yield and composition in *Satureja hortensis* L. Flavour Fragrance Journal. pp. 275-277.

[6] Breemhaar, H.G. and Bouman, A., 1995. Mechanical harvesting and cleaning of *Calendula officinalis* and *Dimorphotheca pluvialis*. Industrial Crops and Products. 4(3), 281-284.

[7] Fageria, N.K., 1992. Maximizing Crop Yields. Marcel Dekker Inc, New York, p. 274.

10/24/2011

[8] Fernandez, G.C.J., 1992. Effective selection criteria for assessing plant stress tolerance. In: Kuo, C.G., (Eds), Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress. Publication, Tainan, Taiwan. 13-18 Aug. Chapter 25, pp. 257-270.

[9] Fischer, R. and Mourer, R., 1987. Drought resistant in spring heat cultivar. i. Grain responses. Aust. Res. 29, 895-97.

[10] Jangir, R.P. and Singh, R., 1996. Effect of irrigation and nitrogen on seed yield of Cumin (*Cuminum cymimum*). Indian. J. Agron., 41,140-143.

[11] Mangel, K., 1992. Nutrition and Metabolism of Plants. Translated by: Haghparast Tanha, M.R., 1996. Publication of Islamic Azad University, Rasht, Iran, p. 198.

[12] Omid beigi, R., 2005. Produce and manufacturing medicinal plants. Astan Quds Razavi's Publication, Mashhad, Iran, p. 347.

[13] Rahmani, N., Valadabadi, S.A., Daneshian, J. and Bigdeli, M., 2008. The effects of water deficit stress and nitrogen on oil yield of *Calendula officinalis* L. Iranian Journal of Medicinal and Aromatic Plants. 24(1), 101-108.

[14] Rosille, A.A. and Hambilin, J., 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci. 21, 43-46.

[15] Safikhani, F., Heydarye-Sharifabadi, H., Syadat, A., Sharifi Ashorabadi, A., Syed Nedjad, M. and Abbaszadeh, B., 2007. The effect of drought on yield and morphologic characteristics of *Deracocephalum moldavica* L. Iranian Journal of Medicinal and Aromatic Plants. 23(2), 183-194.

[16] Shubhra, K., Dayal, J., Goswami, C.L. and Munjal, R., 2004. Effects of water-deficit on oil of Calendula aerial parts. Biologia Plantarum. 48(3), 445-448.