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THE EFFECTS OF N-FERTILIZER RATE ON THE PHYSIOLOGY AND THE YIELD OF SOYBEAN (*GLYCINE MAX* (L.) MERR.) UNDER DIFFERENT IRRIGATION REGIMES

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Abstract

Global Climatic changes are being more and more obvious, resulting in massive fluctuations in the food availability for the increasing world population because of the abiotic stresses resulted from these changes, with drought stress being one of the most serious stresses. Using mineral fertilization was introduced as a proposed solution to overcome the food gap resulted from the above-mentioned factors, but the negative effects of the mineral fertilization on both soil environment and food quality makes it necessary to come out with alternative solutions. Legume crops are able to fix atmospheric nitrogen by the symbiosis process, which reduces the need of mineral N. Soybean is one of the most important legumes with its high content of protein and oil, but is drought-susceptible. An experiment was conducted to investigate the effects of both drought stress and mineral N on the physiology and the yield of two soybean cultivars during 2017 growing season. The results showed that applying N-fertilizer enhanced the physiology of soybean plants, especially under drought conditions; yet, high rates of N-fertilizer did not result

in better yield. It was concluded that the effects of drought stress on soybean are more serious and obvious than of the N fertilization. In addition, adding high rates of N-fertilizer is not always favorable, especially with the absence of drought stress conditions.

Keywords

Soybean, Yield, Drought stress, N fertilization

1. Introduction

Soybean (*Glycine max* (L.) Merr.) is an important legume for both human consumption and animal feeding because it contains high protein and oil concentrations (Liu et al., 2008); soybean provides 60% of human vegetable protein (Rosenthal et al., 1998; Allen et al., 2009), moreover, soybean seeds are the highest in protein concentration (about 40%) compared to other legumes, and are among the highest in oil concentration (about 20%), with also carbohydrates and minerals (Miransari, 2016). Soybean is mostly sown under rain fed scheme, which has put this crop, with the current global climatic changes, under drought stress in many regions as soybean is reported to be drought-susceptible (Liu et al., 2004; Oh and Komatsu, 2015). As a response to drought stress, many morphological and physiological changes are revealed by soybean plants, which in part, lead to growing and development fluctuations (Yamaguchi-Shinozaki and Shinozaki, 2006; Reynolds and Tuberosa, 2008), for example, alleviated stomatal closure to reduce water loss, decreased leaf area and deeper and denser roots to improve water uptake (Imsande, 1992); drought stress also decreases the number of soybean nodes (Frederick et al., 1989) which can lead to reduced plant height.

The leaf area index (LAI) is the canopy density of a crop population, and has an important effect on the final yield (Liu et al., 2008). Normally, shading happens to the lower leaf levels and consequently reduces the (LAI), but drought stress decreases the (LAI) more than mutual shading does (Liu et al., 2008), resulting in less (LAI) values under drought conditions.

Plant height shows the ability of the soybean plants to produce more nodes, and consequently more flowers, pods and seeds. Many papers reported plant height to decrease when drought stress is imposed at different stages of soybean lifecycle (Atti et al., 2004; Mak et al., 2014).

Drought inhibits soybean growth and decreases the yield (Sadeghipour and Abbasi, 2012; Li et al., 2013; Manavalan et al., 2009), moreover, the stage [for example, during pod formation (Sionit and Kramer, 1977), or during seed filling (Turner et al., 2005; Maleki et al., 2013)] at

which the drought stress is imposed leads to different yield loss percentage; Ohashi et al. (2006) reported 20% yield reduction when soybean was subjected to drought stress during the vegetative stages, whereas the reduction reached about 46% when the drought was imposed at the flowering stage, which was supported by Ishibashia et al. (2011) who reported flowering stage to be the most sensitive stage to drought stress; similar results were introduced by Cui et al. (2013). In addition, different soybean genotypes were reported to reveal different yield reductions under drought stress conditions (Bellaloui and Mengistu, 2008; He et al., 2016).

Chlorophyll content is one of the most important physiological traits, as it reflects the plant photosynthesis's, and consequently, yield's potentials. Drought stress influences the chlorophyll content and reduces its value as reported by many researchers (Makbul et al., 2011; Hao et al., 2013). Total chlorophyll content and protein synthesis essentially need nitrogen (N) which is one of the most important macronutrients for plant growth and yield. Moreover, N is also essentially needed for the soybean vegetative growth in order to produce the optimum biomass (Fabre and Planchon, 2000; Fageria and Baligar, 2005). Soybean plants have a large N harvest index compared to other legumes (Lawn, 1989).

Biologically-fixed N_2 and mineral N are the two main sources of N needed in soybean (Salvagiotti et al., 2008). If there is some deficiency in fixed N_2 amounts, other sources (mainly through N fertilization as a quick and partially-convenient method of providing N to plants) must be available (Yinbo et al., 1997; Fabre and Planchon, 2000; Miransari, 2016), or else N from leaves will be remobilized to the seeds, which in part, will lead to decreased photosynthesis and eventually reduced yield (Salvagiotti et al., 2008). Although applying N fertilizer at appropriate rates can enhance seedling growth by becoming established at the beginning of the season until the initiation of biological N_2 -fixation by rhizobia (Ferguson et al., 2010; Seneviratne et al., 2000), higher amounts of N fertilizer can negatively affect *B. japonicum* activity and, hence, N_2 -fixation (Herridge and Brockwell, 1988; Chen et al., 1992; Ying et al., 1992; Hungria et al., 2005), yet it is still a better solution than exposing the plants to N-deficiency which can result in growth delay, especially if it happens during the vegetative stages (Salvagiotti et al., 2008). Therefore, the determination of N fertilizer influence on the growth and the yield of soybean crop is very important in order to maximize yield and economic profitability in a particular environment (Caliskan et al., 2008). Harper (1974) and Imsande (1992) reported seed yield and seed protein content to be enhanced when N_2 -fixation is associated with N fertilizer, particularly during pod filling (Imsande, 1998; Salvagiotti et al., 2008).

N fertilizer is very important under abiotic stresses (Caliskan et al., 2008) like drought stress (Obaton et al., 1982). The addition of N fertilizer to soybean increased drought tolerance as it enhanced the accumulation of both shoot nitrogen and shoot biomass under drought stress conditions (Purcell and King, 1996).

The aim of this experiment was to study the influence of different N fertilizer rates, under two drought stress severities, on the morphology, physiology and yield of two soybean cultivars.

2. Materials and Methods

Two soybean cultivars; *Pannonia Kincse* (middle maturity group) and *Boglár* (very early maturity group), were sown in Debrecen University's experimental site (Látókép) (N. latitude 47° 33', E. longitude 21° 27') on April 26th, whereas the harvest was on September 1st, 2017. The soil type is calcareous chernozem, the average annual precipitation is 565.3 mm, whereas the precipitation between sowing and harvesting dates was 213.3 mm (*Fig. 1*).

Three N fertilizer rates; 0, 35 and 105 kg ha⁻¹ of ammonium nitrate (NH₄NO₃) (0 N, 35 N and 105 N, respectively) were applied under three irrigation regimes; severe drought (SD), moderate drought (MD) and no drought (ND). Each treatment had four replicates.

LAI values were recorded using SS1 – SunScan canopy analysis system (Delta- T Devices, UK) at three growing stages (Fehr and Caviness, 1977); fourth node V4 (LAI 1), full bloom R2 (LAI 2) and full pod R4 (LAI 3). The chlorophyll content was measured using SPAD-502Plus (Konica Minolta, Japan) at the same previously-mentioned growing stages. Plant height was measured manually using a ruler at R2 stage. In every measurement, 10 plants were randomly chosen from each plot, and the average was calculated.

The statistical analysis (2-way ANOVA) was made using SPSS (ver.22) software.

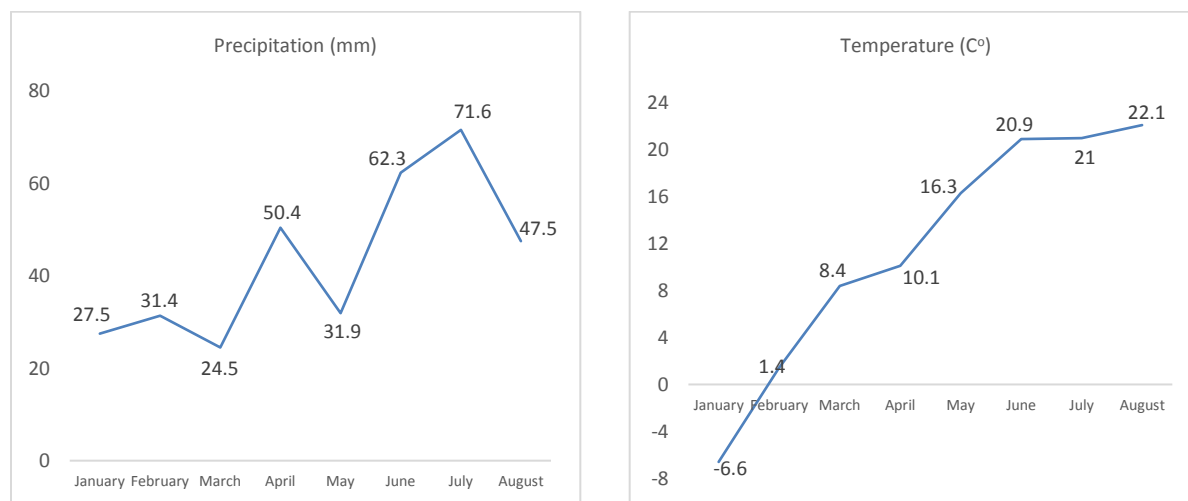


Figure 1: The precipitation (mm) and the temperature (C°) from the beginning of the year of experiment till the harvest date.

3. Results and Discussion

3.1 Chlorophyll content

For cultivar *Pannonia Kincse* under severe stress conditions (SD), apart from a slight decrease in (35 N) treatment at R4 stage compared to (0 N) treatment, the chlorophyll content followed the same trend; increasing N fertilizer rates was accompanied by an increase in the chlorophyll content. Moreover, (105 N) treatment increased the chlorophyll content significantly compared to the other two treatments (0 N and 35 N). Under moderate drought (MD), the chlorophyll content increased as N fertilizer rate increased at V4 and R4 stages, however, during R2 stage, (35 N) treatment (with an average of 45.52) resulted in the highest chlorophyll content; the difference was significant compared to (0 N) treatment (40.48), and insignificant compared to (105 N) treatment (40.75). When the drought was waived off, the chlorophyll content was better in (35 N) treatment than in (0 N) treatment during the three stages. The high rate of N fertilizer resulted in the best chlorophyll content at V4 and R2 stages (43.36 and 43.28, respectively), and, on the contrary, in the lowest chlorophyll content (40.66) at R4 stage (table 1).

At reproductive stages (R2 and R4), the chlorophyll content was better under moderate drought stress compared to severe drought stress when N fertilizer was not applied. Moreover, (ND) treatment was the highest in chlorophyll content at both V4 and R2 stages (table 1). Hossain et al. (2014) found that total chlorophyll content in the leaves of the studied soybean genotypes at vegetative stages (starting from V2 stage) was lower under water deficit than that of well-watered conditions, which is consistent with previous studies on other crops (Cui et al., 2004; Pagter et al., 2005).

Table 1: Chlorophyll content (SPAD), LAI, plant height (cm) and yield (kg ha⁻¹) of *Pannonia Kincse* with different N fertilizer rates under different irrigation regimes

Trait	N rate (kg ha ⁻¹)	Severe drought (SD)			Moderate drought (MD)			No drought (ND)		
		Mean	F	Sig.	Mean	F	Sig.	Mean	F	Sig.
SPAD1	No N	41.25 ^b	17.59	0.00	40.16 ^a	3.73	0.07	42.13 ^a	0.68	0.53
	35 N	41.26 ^b			43.25 ^a			42.78 ^a		
	105 N	45.96 ^a			44.30 ^a			43.36 ^a		
SPAD2	No N	40.11 ^b	2.45	0.14	40.48 ^b	4.96	0.04	42.12 ^a	0.40	0.68
	35 N	42.48 ^b			45.52 ^a			43.16 ^a		
	105 N	43.52 ^a			40.75 ^{ab}			43.28 ^a		



SPAD3	No N	43.36 ^b	3.25	0.09	43.54 ^a	0.82	0.47	41.48 ^a	0.51	0.62
	35 N	41.74 ^b			45.07 ^a			42.65 ^a		
	105 N	44.89 ^a			45.16 ^a			40.66 ^a		
LAI1	No N	2.28 ^b	7.06	0.01	2.06 ^{ab}	6.05	0.02	1.90 ^a	11.09	0.00
	35 N	2.53 ^{ab}			1.94 ^b			2.22 ^a		
	105 N	3.05 ^a			2.48 ^a			2.74 ^a		
LAI2	No N	6.12 ^b	4.30	0.05	5.23 ^a	2.19	0.17	5.34 ^a	31.46	0.00
	35 N	6.90 ^{ab}			6.37 ^a			7.06 ^a		
	105 N	7.46 ^a			7.14 ^a			8.26 ^a		
LAI3	No N	8.50 ^a	0.97	0.42	9.09 ^a	0.66	0.54	9.92 ^c	0.37	0.70
	35 N	8.20 ^a			9.52 ^a			10.35 ^b		
	105 N	10.10 ^a			10.04 ^a			10.56 ^a		
Height	No N	66.75 ^a	0.64	0.55	73.75 ^a	2.27	0.16	67.25 ^a	3.98	0.06
	35 N	64.25 ^a			69.00 ^a			73.00 ^a		
	105 N	68.00 ^a			74.75 ^a			75.50 ^a		
Yield	No N	4335 ^a	0.67	0.54	4220 ^a	0.39	0.69	4746 ^a	0.16	0.86
	35 N	3960 ^a			4325 ^a			4470 ^a		
	105 N	4276 ^a			4185 ^a			4526 ^a		

- Same letter indicates no significant difference at .05 level among N rates within a certain trait under certain irrigation regime.

For cultivar *Boglár*, the different irrigation regimes resulted in very similar tendencies; the chlorophyll content, under severe drought, gradually increased as the rate of N fertilizer increased, with no significant differences at V4 and R2 stages, whereas the difference was significant between (105 N) and (0 N) treatments at R4 stage. The same trend was followed under moderate stress, except for a slight decrease in (35 N) treatment (36.87) compared to (0 N) treatment (36.98) at V4 stage; moreover, the difference was insignificant at V4 and R2 stages, whereas it was significantly higher for (105 N) treatment (43.49) compared to (0 N) treatment (36.84) at R4 stage. When drought stress was waived off, the chlorophyll content gradually and insignificantly increased with increasing N fertilizer rate at all stages (table 2).

When a high rate of N fertilizer was applied, (ND) treatment resulted in the highest chlorophyll content at all stages compared to both severe and moderate drought stress treatments (table 2). Makbul et al., (2011) recorded a significant decrease in chlorophyll content by 28%, and Hao et al., (2013) by 31% of drought-stressed soybean compared to control plants. Similar results were provided earlier by Atti et al. (2004).

3.2 Leaf Area Index (LAI)

The drought did not change the general trend of LAI values for both cultivars with only one exception; for *Pannonia Kincse*, adding a low rate of N fertilizer rate under severe drought stress resulted in better LAI values at both V4 and R2 stages compared to (0 N) treatment, however, adding a high rate of N fertilizer lead to the highest LAI in all stages; the difference was significant compared to (0 N) treatment at both V4 and R2 stages. Under moderate drought,

again (105 N) treatment resulted in the highest LAI value at all stages; moreover, at V4 stage, the difference was significant compared to (35 N) treatment, which resulted in the lowest LAI value. Caliskan et al. (2008) reported LAI values to be increased with increasing N rates. At latter stages (R2 and R4), LAI value insignificantly increased as N fertilizer rate increased. When drought was waived off, LAI values increased as N fertilizer rate increased at all stages; moreover, the differences were significant among the three N fertilization treatments at R4 stage (table 1).

For *Boglár* under (SD) regime, the same tendency of LAI to increase with increased N fertilizer rates was noticed; however, the differences were significant only between (105 N) and (0 N) treatments at R2 stage. Under both (MD) and (ND) regimes, the trend was even more obvious at all stages; the difference between the highest (105 N) rate and the lowest (0 N) rate was significant at V4 and R2 stages, whereas it was insignificant at R4 stage. The exact same tendency was noticed when the drought was waived off (table 2). Previously, DeMooy et al. (1973) and Watanabe et al. (1986) reported that adding N fertilizer before reproductive stages enhances growth and LAI.

At both reproductive stages (R2 and R4), the mean LAI value of *Pannonia kincse* (middle maturity group) (table 1) was higher than that of *Boglár* (very early maturity group) (table 2) indicating that soybean cultivar plays a role in LAI values and in the corresponded yield. Liu et al. (2005) reported higher LAI in late maturity genotypes of soybean compared to early and middle maturity group genotypes; they concluded that this higher LAI values increased solar energy interception, consequently, a greater CO₂-fixation ability which resulted in more assimilates accumulation.

3.3 Plant Height

For *Pannonia Kincse*, (35 N) treatment resulted in the shortest plants under drought (whether severe or moderate). (105 N) treatment resulted in the tallest plants whether the drought was present or waived off. No significant differences were recorded (table 1).

When N fertilizer was applied (regardless of the rate), the plant height gradually decreased as the drought increased (table 1), which is consistent with many previous studies (e.g. Kadhem et al., 1985; Demirtas et al., 2010). Hossain et al. (2014) reported that progressive drought stress significantly decreased plant height of soybean genotypes. Soybean seedling height decreased 4.3% under drought stress (Navari-Izzo et al., 1990), similar results were reported at different stages (Atti et al., 2004; Demirtas et al., 2010; Garcia et al., 2010; Hao et al., 2013; Mak et al.,

2014). In (0 N) treatment, moderate drought stress resulted in the highest value of plant height (73.75 cm), whereas the plants under severe drought stress were the least in height (66.75 cm) (table 1). This reduction might be caused as cell swelling, cell wall and synthesis enzymes are reduced, consequently, growth and plant height are decreased (Levitt, 1980; Austin, 1989).

For *Boglár*, (35 N) treatment resulted in the shortest plants under severe drought, whereas it enhanced this trait under both moderate and no drought treatments compared to (0 N) treatment, however, (105 N) treatment resulted in the tallest plants under all irrigation regimes with no significance recorded (table 2).

In (35 N) treatment, the plant height under (MD) regime was the highest (71.0 cm), and though it was not significantly different from the correspondent value of (ND) (70.0 cm), yet it was from under (SD) regime (66.0 cm). In (105 N) treatment, (ND) resulted in better (72.50 cm) plant height than did (SD) regime (68.75 cm); however, (MD) regime resulted in the highest value (72.75 cm). In (0 N), plant height tended to increase as the available water increased (67.00, 67.50 and 68.25 cm under (SD), (MD) and (ND) regimes, respectively), however, the increase was insignificant (table 2). Sionit and Kramer, (1977) reported no significant differences in plant height under drought stress.

Table 2: Chlorophyll content (SPAD), LAI, plant height (cm) and yield (kg ha^{-1}) of *Boglár* with different N fertilizer rates under different irrigation regimes

Trait	N rate (kg ha^{-1})	Severe drought (SD)			Moderate drought (MD)			No drought (ND)		
		Mean	F	Sig.	Mean	F	Sig.	Mean	F	Sig.
SPAD1	No N	37.50 ^a	0.17	0.84	36.98 ^a	3.82	0.06	37.12 ^a	2.22	0.16
	35 N	38.03 ^a			36.87 ^a			38.66 ^a		
	105 N	38.12 ^a			42.22 ^a			40.91 ^a		
SPAD2	No N	35.00 ^a	3.99	0.06	34.44 ^a	3.55	0.07	37.92 ^a	0.27	0.77
	35 N	35.79 ^a			36.82 ^a			38.00 ^a		
	105 N	38.90 ^a			38.32 ^a			39.21 ^a		
SPAD3	No N	40.23 ^b	4.22	0.05	36.84 ^b	4.65	0.04	36.50 ^a	1.71	0.23
	35 N	41.49 ^{ab}			42.10 ^b			39.23 ^a		
	105 N	44.55 ^a			43.49 ^a			40.13 ^a		
LAI1	No N	2.14 ^a	3.59	0.07	2.02 ^b	6.15	0.02	1.83 ^b	4.35	0.05
	35 N	2.84 ^a			2.23 ^{ab}			2.26 ^{ab}		
	105 N	3.06 ^a			2.82 ^a			3.29 ^a		
LAI2	No N	4.53 ^b	14.80	0.00	5.03 ^b	8.18	0.01	5.09 ^b	4.12	0.05
	35 N	6.17 ^{ab}			5.97 ^{ab}			5.95 ^{ab}		
	105 N	7.90 ^a			7.00 ^a			7.27 ^a		
LAI3	No N	7.56 ^a	2.31	0.15	8.70 ^a	1.32	0.32	9.50 ^a	0.99	0.41
	35 N	8.15 ^a			8.95 ^a			9.60 ^a		
	105 N	8.96 ^a			9.43 ^a			10.62 ^a		
Height	No N	67.00 ^a	0.37	0.70	67.50 ^a	2.69	0.12	68.25 ^a	1.55	0.26
	35 N	66.00 ^{a 2}			71.00 ^{a 1}			70.00 ^{a 12}		
	105 N	68.75 ^a			72.75 ^a			72.50 ^a		
Yield	No N	3659 ^a	0.17	0.85	4576 ^a	0.89	0.44	5063 ^a	1.84	0.21
	35 N	3854 ^a			4717 ^a			5379 ^a		

	105 N	3753 ^{a 2}			4957 ^{a 1}			4697 ^{a 12}		
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- Same letter indicates no significant difference at .05 level among N rates within a certain trait under certain irrigation regime.
- Same number indicates no significant difference at .05 level among irrigation regimes within a row (within a certain N fertilizer rate).

3.4 Yield

For cultivar *Pannonia Kincse*, the yield was the highest (4335.0 kg ha⁻¹) in (0 N) treatment under (SD) regime, however, applying a high rate of N fertilizer resulted in a better yield (4276 kg ha⁻¹) than did the application of a low rate (3960 kg ha⁻¹). Under (MD) regime, the addition of a high rate of N fertilizer resulted in the lowest yield (4185 kg ha⁻¹), whereas the addition of a low rate of N fertilizer resulted in the highest yield (4325 kg ha⁻¹) (table 1). The reasons for the alterations in response to N fertilization are not accurately specified; however, environment and stresses, initial soil fertility, nodulation capacity, inoculant presence in soil and pre-sowing inoculation, and the timing of N application all have a role (Gault et al., 1984; Peoples et al., 1995). When drought was waived off, the trend of the yield matched that under severe drought; applying a high rate of N fertilizer resulted in a better yield (4526 kg ha⁻¹) than did the application of a low rate (4470 kg ha⁻¹), however, the yield was the highest (4746 kg ha⁻¹) when no N fertilization was applied (table 1). Kaschuk et al. (2016) concluded that N fertilizer did not lead to more yield of two different soybean cultivar groups (determinate and indeterminate) whether N application was at sowing time, during reproductive stages or both; it even resulted in a slight, insignificant yield loss when it was applied at R2 stage, which was previously reported (Hungria et al., 2006; Mendes et al., 2008). Previously, many researchers reported N-fertilizer application to reduce soybean yield (e.g. Welch et al., 1973; Deibert et al., 1979; Hardarson et al., 1984; Herridge and Brockwell, 1988; Ying et al., 1992).

Regardless of N application and rate, the yield was the best when the drought was waived off, indicating that the drought stress has more influence on soybean yield than N fertilization has (table 1). Ergoa et al. (2018) reported that under water stress, yield decreased 43% due to both lower grain number and grain weight compared to controls.

For *Boglár*, (35 N) treatment resulted in the highest yield under severe drought stress conditions (3854 kg ha⁻¹), which exceeded the yield of (105 N) treatment (3753 kg ha⁻¹), though the difference was insignificant, and (0 N) treatment resulted in the least yield (3659 kg ha⁻¹). Under moderate drought, the mean yield was increased with increasing N-fertilizer rates; however, the differences were insignificant (table 2). Some researchers concluded that N

fertilizer addition increases yield (Watanabe et al., 1986; Nakano et al., 1987; Norhayati et al., 1988; Takahashi et al., 1991) by reducing abortions of flowers and pods (Brevedan et al., 1978). Chen et al. (1992) reported that every 1 kg ha⁻¹ of N fertilizer resulted in extra 1.2 kg ha⁻¹ seeds under drought stress. Later, Purcell and King (1996) reported that under drought stress, N fertilizer increased the yield to (2798 kg ha⁻¹) compared to (2373 kg ha⁻¹) without N fertilizer; they associated this increase with increased seed number because of decreased flower and pod abortion. N fertilizer was reported to be very important under abiotic stresses (Caliskan et al., 2008; Salvagiotti et al., 2008) like drought stress for example (Lyons and Earley, 1952; Obaton et al., 1982). Moreover, the addition of N fertilizer to soybean increased drought tolerance as it enhanced the accumulation of both shoot nitrogen and shoot biomass under drought stress conditions (Purcell and King, 1996). When drought stress was waived off, (35 N) treatment resulted in the best yield (5379 kg ha⁻¹), and (105 N) treatment resulted in the lowest yield [4697 kg ha⁻¹, compared to 5063 kg ha⁻¹ for (0 N) treatment], indicating that high rate of N fertilizer is not recommended under (ND) regime for this cultivar (table 2). Under well-watered conditions, N (at a rate of 336 kg ha⁻¹) decreased yield to (2597 kg ha⁻¹) relative to (2728 kg ha⁻¹) (Purcell and King, 1996).

Regardless of N application and rate, the yield was better under moderate drought than under severe drought (table 2), which is consistent with Dornbos and Mullen (1992) conclusions; severe drought stress reduced the seed yield of soybean more than did moderate drought stress. The addition of a high rate of N fertilizer under (ND) regime did not result in the highest yield (4697 kg ha⁻¹, compared to 4957 kg ha⁻¹ under moderate drought stress conditions); however, the yield achieved under (SD) regime was significantly lower (3753 kg ha⁻¹) (table 2). Many previous studies reported a yield reduction under drought stress (e.g. Kokubun, 2011; Karam et al., 2005; Dogan et al., 2007; Bajaj et al., 2008; Sincik et al., 2008; Gercek et al., 2009; Sadeghipour and Abbasi, 2012; Li et al., 2013), although different timings of drought stress application were suggested to be responsible for different yield-loss amounts (Turner et al., 2005; Demirtas et al., 2010; Maleki et al., 2013).

Under (SD) regime, the average yield of all N-fertilization treatments was higher (4190 kg ha⁻¹) for *Pannonia Kincse* than was for *Boglár* (3755 kg ha⁻¹), whereas it was lower under (MD) (4243 compared to 4750 kg ha⁻¹, respectively) and (ND) regime (4580 compared to 5046 kg ha⁻¹, respectively) (tables 1 and 2). Garcia et al. (2010) reported that soybean genotypes significantly differ in yield production under drought stress conditions and also within the interaction between

the drought stress and the genotype; similar conclusions were reported (Brown et al., 1985; Bellaloui and Mengistu, 2008; Maleki et al., 2013; He et al., 2016).

4. Conclusions

Although our experiment was a one-growing-season experiment, some initial conclusions could be achieved; in most cases, under different irrigation regimes, the chlorophyll content of both cultivars tended to be the highest when a high rate of N fertilizer was applied; this could be understood because of the important role of N in photosynthesis formula. Similar conclusions were observed regarding LAI.

Adding N fertilizer to *Pannonia Kincse* resulted in progressively better plant height with progressively better water availability, whereas the same tendency was observed for *Boglár* when no N fertilization was applied; this might be a genotype-dependent response, however, further investigation should be conducted.

Regardless of N application and rate, the yield of *Pannonia Kincse* was the best when the drought was waived off; also for *Boglár*, the yield was better under moderate drought than under severe drought, indicating that drought stress has more influence on soybean yield than N fertilization has. Moreover, when drought was waived off, the addition of a high rate of N fertilizer did not result in the highest yield, suggesting that it is not always recommended to apply high rates of N fertilizer, especially when there is no drought stress hazard; many previous papers reported same conclusion. More progress and more precise conclusions are expected after extending our experiment over the next growing seasons.

As the experiment was conducted in the field, the main limitation was to control the timing of drought stress, however, precise information retrieved from the meteorological station in the experimental site made it possible to understand the drought conditions within the site.

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