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EFFECT OF PHOSPHORUS AND NITROGEN FERTILIZERS, IRRIGATION SYSTEMS AND MYCORRHIZAL INFECTION ON SOYBEAN NODULATION

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Two experiments were carried out in the experimental farm at Shalakan in the Kulubia Governorate in Egypt in the summer of both 1996 and 1997 to study the effect of nitrogen and phosphorus fertilizers, irrigation systems, and mycorrhizal effect on nodulation and mycorrhizal spores production on soybean.

Soybean *(Glycine max*(L)Merr *)* Giza 21 cultivar was planted using three irrigation systems drip, furrow and sprinkler convention with two levels of nitrogen fertilizer (0 N and 35.7 kg N ha^{-1}) with two forms of phosphorus super phosphate containing 15.5% P_2O_5 and rock phosphate containing 26% P_2O_5 and with two mycorrhizal infection (VAM treatment and without VAM).The number and dry weight of nodules were significantly influenced by drip> furrow> sprinkler irrigation at stage of full bloom (R_2) and beginning of seeds (R_5) stages. The highest amount of nitrogen fertilizers, (35.7 kg N ha^{-1} significantly increased the number of nodules $plant^{-1}$ compared to the control treatment. The interaction effect between irrigation and nitrogen fertilizer at R_2 and R_5 for the number of nodules $plant^{-1}$ and at R_5 for the dry weight were mainly as those of adding nitrogen fertilizer at a rate of 35.7 kg N ha^{-1} under furrow irrigation . The number and dry weight of nodules $plant^{-1}$ were significantly increased by infestation of fungus vesicular arbuscular mycorrhizea, VAM. Infestation of soil by VAM significantly influenced the number of mycorrhizal spores in the rhizosphere of soybean plants grown under different irrigation systems. Percent maximum root infection occurred under drip irrigation followed by sprinkler irrigation and the minimum infection under furrow irrigation.

Keywords: soybean, phosphorous forms, nitrogen fertilizer, irrigation systems, Mycorrhizae, nodulation

Egypt is a country with high alkaline soils and of low phosphorus availability for plants. By decreasing the soil pH, inoculation of soil with mycorrhizae increased the total allocation of C to the roots by 4-7 % (Harris *et al.,* 1985). Subsequently this reduces the soil pH, and phosphorus is converted from unavailable to available form. Soybean has a great ability to fix atmospheric nitrogen in root nodules. Nodulation is controlled by inoculation with *Bradyrhizobium japonicum* bacteria and other factors, such as starter nitrogen (Eaglesham *et al.,* 1983) and phosphorus fertilizer. The number and dry weight of nodules were reported to increased with increasing nitrogen application (Nagra *et al.,* 1991). Both nitrogen and phosphorus fertilizers were reported to have effect on growth, nodulation and yield of soybean , but no interaction between them was found (Yinbo *et al.,* 1998). Adequate amount of phosphorous fertilizer added to soybean plant enhanced the growth of N_2- fixing bacteria through increasing the number and dry weight of nodules (Tomar *et al.,* 1991). Nodulation failed in soybean grown without phosphorus (Surenda *et al.,* 1995). Ishac *et al.* (1986) found that *Bradyrhizobium japonicom* inoculation combined with phosphorus fertilization in the form of rock or superphosphate stimulated mycorrhizal development , soybean growth and yield. Symbiosis between fungi and plant roots to form a mycorrhizae involves extensive interactions between both plant and fungi. Some interactions between mycorrhiza and soil microorganisms involve nutrient cycling. Chang *et al.* (1992) found that dual inoculation with soybean Rhizobium and mycorrhizae increased P uptake in addition to increasing the number of nodule and nodule dry weight. Application of rock phosphate and or vesicular- arbuscular mycorrhizea (VAM) fungi increased dry matter yield, seed production, number and weight of nodules and total content of nitrogen (Cardoso, 1985). In addition, VAM infestation stimulated nitrogen fixation which in turn resulted in better growth of mycorrhizae and nodulation (Vejsadova, *et al.,* 1990). In order to promote soybean production in the new lands in Egypt, experiments were carried out to study the effect of nitrogen fertilizer VAM inoculation and from of phosphorus fertilizers under drip, sprinkler and modified furrow irrigation systems on soybean nodulation.

MATERIALS AND METHODS

Two field experiments were carried out in summer 1996 and 1997 in experimental farm of Ain Shams University at Shalakan, Kalubia Governorate to study the effect of nitrogen fertilizer, phosphorus forms, irrigation systems and mycorrhizal infestation on nodulation and mycorrhizae infestation of soybean roots Giza 21 cultivar. Every experiment included 24 treatments arranged in split–split –split plot design in 4 replicates. They were the combinations of three irrigation systems (sprinkler, drip, modified furrow) as main plots, 2 levels of inorganic nitrogen fertilizer (0 and 35.7 kg N ha^{-1}) as sub-plots, 2 forms of inorganic phosphorus fertilizer at a rate of 53.55 kg P_2O_5 ha^{-1} as calcium super-phosphate 15.5% P_2O_5 ha^{-1} and rock phosphate 26% P_2O_5 as sub-sub plots and 2 mycorrhizal inoculation (without or with mycorrhizae) as sub-sub-sub plots. In addition a sample of five plants from every treatment of four replicates were chosen randomly after full bloom (R_2) and beginning of seed (R_5) stages of cultivation and prepared for counts of nodule number $plant^{-1}$ as well as weight of nodules. Percentage of root infection with VA mycorrhizae were determined by slide method after staining of root samples with trepan blue (Philips and Hayman,1970). The number of mycorrhizal spores in the soil after harvest were estimated according to the method described by Gerdemann and Nicolson (1963).

RESULTS AND DISCUSSION

Data were statistically analysed using the appropriate analysis of variance. Means were compared by using L.S.D. at 5% level of significancy (Snedecor and Cochran, 1980). Nodulation of soybean roots had been examined as number of nodules $plant^{-1}$ and as dry weight of nodules $plant^{-1}$.· (Tables 1-6) through studying the effect of irrigation system, nitrogen application ,colonization with VAM phosphorus forms and their interactions at R_2 and R_5 on soybean . The addition of nitrogen fertilizer at the rate of 35.7 kg N ha^{-1} to soybean significantly increased the number of nodules $plant^{-1}$ compared to control treatment Table 1. Data from 1996 and 1997, at R_2, show increased of 117.0 and 72.0% in nodules number, and at R_5 (91.0 and 34.0%) for dry weight of nodules $plant^{-1}$, respectively. Several studies have demonstrated the significant contribution of atmospheric N fixation to soybean nutrition and growth (Rennie *et al.*, 1982). Most estimates show that soybean derives between 25 and 75% of its N_2 needs from N_2 fixation (Deibert *et al.*, 1979). The number and dry weight of nodules were influenced significantly by irrigation system with furrow> drip > sprinkler irrigation. These results were similar at R_2 and R_5 stages. The interaction between irrigation systems and nitrogen fertilizer indicated that the highest numbers and dry weight of nodules plant^{-1} were obtained by adding nitrogen fertilizer at a rate of 35.7 kg hac^{-1} under furrow irrigation at both stages. The number and dry weight of nodules plant^{-1} were increased significantly by infestation of mycorrhizal fungus (VAM). Tables (3 and 4). The rate of increase dose of non- infestation by VAM at R_2 and R_5 stages reached 24.0% and 49.0% for the number of nodules and 49.0 and 45.0% for the dry weight of nodules, respectively. Pacovsky *et al.* (1986) indicated that the dry weight of nodulated VAM plants were 50 to 60% greater than those of the non-nodulated VAM control. The interaction between infestation by mycorrhizal fungus and irrigation system on the number and the dry weight of nodules plant^{-1} were significant. Maximum values of the dry weight of nodules plant^{-1} were obtained by inoculation with VAM under furrow irrigation at R_2 and R_5 stages. The number and dry weight of nodules were the least in plants not receiving mycorrhizal under sprinkler irrigation. (Tables 3 and 4). Adding phosphorus fertilizer in the form of rock phosphate increased the number and dry weight of nodules plant^{-1} over those amended with superphosphate at R_2 and R_5 stages. At R_2, there were no significant differences between phosphorus form and irrigation systems on the number and dry weight of nodules plant^{-1}. These results were similar to those obtained by Ishac *et al.* (1986). The effect of nitrogen application, colonizaion by mycrrohizal fungi VAM and phosphorus form under drip, furrow and sprikler irrigation systems and their interactions on both mycorrhizal spore percent and VAM root infection are reported in tables (7,8 and 9, respectively). Nitrogen application as well as phosphorus fertilizer form effects on the spore percent and VAM root infection were not significant for the different irrigation systems. Infestation of soil by VAM caused significantly higher number of mycorrhizal spores in the soil collected from soybean plants rhizosphere under different irrigation systems (Table 8). The rates of increase were 67.0, 91.0, and 58.0%, when compared with no infestation for plants grown under drip, furrow and sprinkler irrigation, respectively. Infection with mycorrhizal spore also caused similar trend in VAM root infection percentage. Significantly higher percent root infection value was obtained under drip irrigation compared with sprinkler irrigation and the least infection occurred with furrow irrigation. These results might be attributed to the effect of O_2 and CO_2 level on VAM since VAM are aerobic microorganisms (Saif, 1984). Therefore, soil water and aeration have considerable impact on the distribution, effectiveness and plant response to VAM.

TABLE (1). Effect of nitrogen application and irrigation systems on number of nodules plant^{-1} (combined data of 1996 and 1997) .

R_2				
Irrigation systems				
	Drip	Furrow	Sprinkler	Means
Nitrogen	60.92	113.74	54.96	76.51
Without	28.03	55.47	22.44	35.41
Means	44.48	84.60	38.86	55.97
LSD(R_2):I=1.055 N=S IxN=1.48				
R_5				
	Drip	Furrow	Sprinkler	Means
Nitrogen	83.06	134.16	107.57	108.69
Without	48.98	61.26	59.50	55.85
Means	66.59	96.60	83.41	82.34
R_5 :I=1.41 N=S IxN=1.99				

R_2= Stage of full bloom
R_5= stage of beginning seed

TABLE (2). Effect of nitrogen application and irrigation systems interaction on dry weight of nodules(g) plant^{-1} (combined data of 1996 and 1997).

R_2				
Irrigation systems				
	Drip	Furrow	Sprinkler	Means
Nitrogen	0.25	0.80	0.22	0.29
Without	0.09	0.25	0.06	0.16
Means	0.17	0.33	0.140	0.21
LSD(0.05) I=0.011 N=S I x N= NS				
R_5				
	Drip	Furrow	Sprinkler	Means
Nitrogen	1.90	2.04	0.93	2.25
Without	0.92	1.15	0.59	0.79
Means	1.26	1.59	0.94	1.27
LSD(0.05) I=0.092 N=S Ix N= NS				

R_2= Stage of full bloom
R_5= stage of beginning seed

TABLE (3). Effect of infestation with mycorrhizal Fungi(VAM), irrigation systems and their interaction on number of nodules plant^{-1} (combined data of 1996 and 1997)

R_2				
Irrigation systems				
	Drip	Furrow	Sprinkler	Means
VAM	54.28	83.77	50.43	62.57
Without	38.88	85.44	27.25	49.38
Means	44.48	84.60	38.84	55.97
LSD(0.05) I= 1.059		VAM=S		IxVAM=1.484
R_5				
	Drip	Furrow	Sprinkler	Means
VAM	87.72	108.64	99.98	98.79
Without	45.55	86.70	67.11	66.44
Means	66.64	97.72	83.53	76.07
LSD(0.05) I= 1.415		VAM=S		IxVAM=2.75

R_2= Stage of full bloom
R_5= stage of beginning seed

TABLE (4). Effect of infestation with mycorrhizal fungi(VAM), irrigation systems and their interaction on dry weight of nodules(g) plant^{-1} combined data of (1996 and 1997)

R_2				
Irrigation systems				
	Drip	Furrow	Sprinkler	Means
VAM	0.22	0.36	0.17	0.31
Without	0.11	0.28	0.10	0.16
Means	0.17	0.32	0.14	0.21
LSD(0.05) R_2: I=0.009		VAM= S		IxVAM=.008
R_5				
	Drip	Furrow	Sprinkler	Means
VAM	1.54	1.80	1.11	1.49
Without	0.97	1.38	0.73	1.02
Means	1.26	1.59	0.95	1.14
LSD(0.05) R_5: I=0.03		VAM=S		IxVAM=.055

R_2= Stage of full bloom
R_5= stage of beginning seed

TABLE (5). Effect of phosphorus forms , irrigation systems and their interactions on no umber of nodules plant^{-1} (combined data of 1996 and 1997)

R_2				
Irrigation systems				
	Drip	Furrow	Sprinkler	Means
Rock	44.69	87.44	32.0	55.04
Super	44.03	81.80	45.33	47.12
Means	44.50	84.63	38.86	55.97
LSD(0.05) I=1.055	P=S	IxP = NS		
R_5				
	Drip	Furrow	Sprinkler	Means
Rock	70.54	114.58	79.56	85.82
Super	62.73	80.72	87.22	76.87
Means	66.6	97.62	83.39	82.53
LSD(0.05) I= 1.41	P=S	IxP=2.88		

R_2= Stage of full bloom
R_5= stage of beginning seed

TABLE (6). Effect of phosphorus forms , irrigation systems and their interaction on dry weight of nodules (g)plant^{-1}(combined data of 1996 and 1997)

R_2				
Irrigation systems				
	Drip	Furrow	Sprinkler	Means
Rock	0.18	0.34	0.15	0.22
Super	0.16	0.31	0.14	0.82
Means	.17	0.90	0.15	1.03
LSD(0.05) I=0.011	P= S	IxP=NS		
R_5				
	Drip	Furrow	Sprinkler	Means
Rock	1.49	1.83	0.93	1.42
Super	1.02	1.35	0.94	1.11
Means	1.26	1.36	0.94	1.26
LSD(0.05) I=0.031	P=S	IxP=0.056		

R_2= Stage of full bloom
R_5= stage of beginning seed

TABLE (7). Effect of nitrogen application and irrigation systems on the numbers of VA mycorrhizal spores and infection percentages in soybean roots.

Treatment	VAM Spore Nox10^3kg^{-1} soil				VAM infection(%)			
	Drip	Furrow	Sprinkler	Mean	Drip	Furrow	Sprinkler	Mean
Nitrogen	4.54	3.96	4.5	4.33	49.38	44.48	46.25	46.7
Control	4.48	3.88	4.47	4.27	49.9	44.04	49.35	47.76
Mean	4.51	3.91	4.50	4.31	49.64	44.26	46.3	46.73
L.S.D(0.05)	I=0.18		N_2:NS		I=0.86		N_2:NS	

TABLE (8). Effect of VA mycorrhizal inoculation on number of spores and infection Percentages in soybean plants under three irrigation systems .

Treatment	VAM Spore Nox10^3kg^{-1} soil				VAM infection(%)			
	Drip	Furrow	Sprinkler	Mean	Drip	Furrow	Sprinkler	Mean
VAM	5.64	5.14	5.52	5.43	59.06	47.81	54.37	53.74
Control	3.37	2.69	3.5	3.18	40.22	35.71	38.23	38.05
Mean	4.51	3.91	4.50	4.31	49.64	44.26	46.3	46.73
L.S.D(0.05)	I=0.18		VAM:S		I= 0.86		VAM:S	

TABLE (9). Effect of phosphorus source and irrigation systems on the numbers of VA mycorrhizal spores and infection percentages in soybean roots.

Treatment	VAM Spore Nox10^3kg^{-1} soil				VAM infection(%)			
	Drip	Furrow	Sprinkler	Mean	Drip	Furrow	Sprinkler	Mean
Rock	4.56	3.96	4.60	4.37	51.56	45.63	48.23	48.47
Super	4.51	3.88	4.41	4.26	47.72	42.89	44.37	45.00
Mean	4.51	3.91	4.50	4.31	49.64	44.26	46.3	46.73
L.S.D(0.05)	I=0.18		P:NS		I=0.86		P:NS	

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تأثير التسميد الفوسفاتي والنيتروجيني ونظم الرى والتلقيح بالميكورهيزا على تكوين العقد البكتيرية بفول الصويا

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أجريت تجربتان حقليتان بمحطة التجارب الزراعية بشلقان لكلية الزراعة جامعة عين شمس بمحافظة القليوبية الموسم الصيفى عامى ١٩٩٦، ١٩٩٧ لدراسة أثر التسميد الفوسفاتى (سوبر فوسفات الكالسيوم ١٥،٥% فو٢ أ٥ والفوسفات الصخرى ٢٦% فو٢ ا٥) والنيتروجين (صفر ن، ٣٥,٧ كجم ن للهكتار) تحت نظم رى مختلفة (الرش، التنقيط، السطحى المطور) والتلقيح بالميكورهيزا(تلقيح وبدون تلقيح)على إنتاج العقد الجذرية وجراثيم الميكورهيزا بنبات فول الصويا (صنف جيزه ٢١). وكانت النتائج كالتالى:

١- أمكن الحصول على أكبر أعداد ووزن جاف للعقد الجذرية معنويا بالرى بالتنقيط على حين كانت أقل القيم بالرى بالرش بينما أعطى الرى السطحى المطور قيما متوسطة. وذلك فى مرحلة إكتمال الأزهار ومرحلة تكوين البذور.
٢- أدى معدل ٣٥,٧ كجم ن للهكتار الى زياده معنوية فى اعداد العقد البكتيرية للنبات مقارنة بمعاملة المقارنة.
٣- كان للتفاعل بين نظم الرى والتسميد النيتروجينى لمراحل النمو المذكورة تأثير على أعداد العقد البكتيرية للنبات خاصة عند إضافة ٣٥,٧ كجم ن للهكتار تحت نظم الرى السطحى المطور.
٤- أدت إصابة النباتات بالميكورهيزا الى زيادة معنوية فى أعداد والوزن الجاف للعقد البكتيرية.
٥- زادت أعداد جراثيم الميكورهيزا فى منطقة الجذور تحت نظم الرى المختلفة بإضافة الميكورهيزا الى التربة.
٦- ازدادت إصابة الجذور بالميكورهيزا بالرى بالتنقيط على حين نقصت بالرى السطحى المطور وكانت القيم متوسطة بالرى بالرش.