Minufiya J. Agric. Res. Vol.38 No. 2 (1): 423 - 443 (2013) "http://www.mujar.net"

EFFECT OF MAGNETIZED IRRIGATION WATER ON MINERAL NITROGEN FERTILIZATION EFFICIENCY, NUTRIENTS AVAILABILITY AND PEA PLANTS PRODUCTIVITY

Sally A. Midan[1] and Manal F. Tantawy[2]
[1] Horticultural Dept., Faculty of Agric., Minufiya Univ., Shibin El-Kom , Egypt .
[2] Soils , Water and Environment Res. Inst., Agric. Res. Center , Giza , Egypt .

(Received : Feb. 10, 2013)

ABSTRACT: *A field experiment was carried out on alluvial clay soil of the Experimental Farm , Faculty of Agriculture , Minufiya University , Shibin El – Kom , Egypt during two successive growth winter seasons , i. e. 2011 and 2012 on pea plants (Pisum sativum L.), Master – B cv. to evaluate the individual and combined effect of magnetized irrigation water and mineral nitrogen fertilization levels (0 ,50 , 75 and 100 % of recommended dose which are zero , 100 , 150 and 200 kg ammonium sulphate / fed. , respectively) on soil salinity , available N , P and K , also Pea plants growth , productivity and its content of N , P and K were determined . The design of the experiment was complete randomized block with three replicates .*

The obtained data show a decrease in soil salinity and increase in its content (mg kg^{-1}) of available N , P and K in the different layers of the soil irrigated by magnetized water compared with these found with non-magnetized water . The effect of nitrogen fertilization on the determined soil properties was varied . There are a significant increases of plant height (cm) , number of branches / plant , number of leaves / plant , leaf area (cm^2) , root length (cm) , number of pods / plant , number of seeds / pod and pod length (cm) as a result irrigation using magnetized water compared with these parameters values resulted from irrigation using non-magnetized water . Similar significant increases in these parameters were found with the increase of added N . In addition , fresh and dry weights (g / plant) of roots , shoots and seeds, green weight of pods / plant and also both early and total yields (ton / fed.) were increased significantly in the plants irrigated by magnetized water . Similar effect were occurred with mineral nitrogen fertilization additions . Roots , shoots and seeds contents (% and mg kg^{-1}) of N , P and K were obviously augmented with the incremental addition of N specially in the plants irrigated by magnetized water . Irrigation using magnetized water also enhanced the agronomic efficiency of mineral nitrogen fertilizer , wherever the high early and total yields of Pea were obtained by application of 75 % of recommended dose of N fertilizer . So , under irrigation with magnetized water may be rationalization use of mineral – N fertilization .

Key words : *PEA plants , Magnetized water , Mineral nitrogen fertilizer , Soil properties and Growth parameters .*

INTRODUCTION

In arid and semi – arid regions sustainable agriculture development is influenced to a great extent by water quality that might be used economically and effectively in developing agriculture programs . The water treated by the magnetic field or pass through a magnetic device called magnetized water . The effects of magnetic fields on running water have been observed for years . This technology was used in many countries , the successful use of magnetic in treating water for irrigation , industry and home use (Hozayn and Abdul Qados , 2010) .

Till 1980 a little were known about how the magnetic field can stimulate plant growth or even prevent it . According to the data obtained from Russia , Australia , Poland , Turkey , Portugal , England , United States , China and Japan (Celik *et al* . , 2008 and Shabrangi and Majd , 2009) , decrease of soil alkalinity , increase in mobile forms of fertilizers , increase in crop yields and earlier vegetation periods can be achieved by magnetized water treatment . Tai *et al.* (2008) observed that on subjecting water to magnetic field , it leads to modification of its properties , as it becomes more energetic and more able to flow which can be considered as a birth of science called magneto biology . They also pointed out that, magnetized water prevents harmful metals such as , lead and nickel from uptake by roots and reaching fruits and roots. Also , increases the percentage of nutrient elements like phosphorus , potassium and zinc . However , in Egypt the available studies and application of this technology in agriculture is very limited .

In addition , Grewal and Maheshwari (2011) showed that treatment of irrigation water led to a significant increase in shoot dry weight (25 % for snow pea and 20 % for chick pea) and contents of N , K , Ca , Mg , S , Na , Zn , Fe and Mn in both seedling varieties compared with control seedlings . Likewise , there were significant increases in shoot dry weight (11 % for snow pea and 4 % for chick pea) . The results of this study suggest that both magnetic treatment of irrigation water and seeds have the potential to improve the early seedling growth and nutrient contents of seedling .

Nitrogen is an element required for plant growth . It is a fertilizer in a balance and rational way to keep high and stable yield in important component of proteins , enzymes and vitamins in plant . It is a central part of the chlorophyll and essential photosynthetic molecule . The excessive application of mineral fertilizers led to increase production cost . The residual of mineral fertilizers has seriously affected the quality of agricultural products people's health and caused environmental pollution . Therefore a great interest has been generated to apply bioorganic and inorganic fertilizers to establish a good ecoenvironment (Basak, 2006) . Nitrogen fertilizers are economically an expensive input . In many instances less than 60 % of the added N is recovered in the (crop + soil) with the remainder being lost by processes such as volatilization , leaching , immobilization and denitrification. Thus , it is necessary to develop fertilizer management practices that can reduce losses and increase the nitrogen use efficiency (Yusron and Phillips , 1997) .

Pea (*Pisum sativum L.*) is one of the most important winter vegetable crops as fresh or frozen green seeds after cooking . Seeds of pea are considered as a good source of protein , carbohydrates and nutrient elements. Therefore , much attention has been given to improve the productivity of pea through improving the vegetative growth of the plant , total green yield and its quality . El – Dakkak *et al* . (2005) evaluated 17 genotypes of pea under Sohag Governorate conditions , and found that Master – B cv. was characterized with 69.17 day as a maturity date , plant height (70.05 cm) , number of branches per plant (3.07) , pod length (9.77 cm) , number of seeds per pod (6.45) and weight of green pod yield per plant (203.1 g) .

This study was carried to evaluate both individual and combined effects of magnetized irrigation water and different levels of mineral N fertilizer applications on soil salinity and its content of available N , P and K and their redistribution through different soil layers and also on growth parameters , yield and nutrients content of Pea plants . Also , magnetized irrigation water effect on mineral N fertilizer efficiency and its agronomic efficiency were determined . Finally , the rationalization use of mineral – N fertilization is the one important aim of this study .

MATERIALS AND METHODS

A field experiment was carried out on alluvial clay soil of the Experimental Farm , Faculty of Agriculture , Minufiya University , Shibin El – Kom , Egypt during two successive growth winter seasons , i. e. 2011 and 2012 on pea plants (*Pisum sativum L.)* , Master – B cv. to study the effect of magnetized irrigation water under different levels of mineral nitrogen fertilization on alluvial soil salinity , available of some macronutrients and soil productivity of Pea plants . Content of N , P , K and the agronomic efficiency of mineral nitrogen fertilizer were also determined . All agricultural practices beginning from preparation of soil to planting until harvesting were carried out as recommended by Ministry of Agriculture .

Before planting , soli samples of the experimental soil were taken separately at soil depth of 0 – 15 , 15 – 30 , 30 – 60 and 60 – 90 cm , air – dried , ground , sieved through a 2 mm sieve , kept and analyzed for some physical and chemical properties and its content of available N , P and K according to the methods described by Cottenie *et al*. (1982) ; Page *et al*. (1982) and Kim (1996) . The obtained data were recorded in Table (1) . Samples of both non-magnetized (Nile River water of Bahr Shibin El – Kom , Minufiya Governorate) and magnetized water for the same resource were taken before irrigation and analyzed for its chemical composition according to the methods described by Cottenie *et al*. (1982) .The obtained data were recorded in Table (2).

Table (1) : Some physical and chemical properties of the experimental soil .

Soil properties	Units	Soil depth (cm)			
		0 -15	15 -30	30 - 60	60 - 90
Particles size distribution	%				
Coarse sand	%	2.58	2.50	2.35	2.10
Fine sand	%	23.42	23.00	22.10	20.90
Silt	%	34.00	34.50	35.00	36.10
Clay	%	40.00	40.00	40.55	40.90
Textural grade		Clay loam	Clay loam	Clay loam	Clay loam
pH in 1: 2.5 (soil : water) susp.		7.60	7.72	7.78	7.80
EC in soil paste	dSm^{-1}	1.40	1.58	1.75	1.82
Organic mater (OM)	%	1.90	1.20	0.90	0.78
Calcium carbonate ($CaCO_3$)	%	2.10	2.40	2.50	2.55
Cation exchange capacity (CEC)	cmol kg^{-1}	35.30	32.50	25.40	22.50
Available N	mg kg^{-1}	55.20	43.17	28.50	20.15
Available P	mg kg^{-1}	7.25	5.50	4.20	3.50
Available K	mg kg^{-1}	115.20	105.50	88.10	80.70

Table (2) : Chemical composition of the used non-magnetized and magnetized water (NMW and MW) as mean values in the two growing seasons .

Water type	pH	EC dSm^{-1}	Soluble cations (meq l^{-1})				Soluble anions (meq l^{-1})			SAR
			Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	HCO_3^-	SO_4^{-2}	
NMW*	7.22	0.42	1.75	0.60	1.15	0.70	1.42	1.50	1.28	1.82
MW**	7.10	0.43	1.69	0.63	1.20	0.78	1.40	1.48	1.42	1.70

*NMW magnetized water.
**Non-magnetized water

The design of the experiment was complete randomized block with three replicates . The experimental plots were 24 unit and the area of each plot was 12 m² including four ridges (5 m length × 0.6 m width) . Before planting the experimental plots were divided into two main groups (12 plots / main group) , which treated with one of irrigation water type (magnetic and non-magnetic) . The sub main plots were treated with ammonium sulphate (21.5 % N) at rates of 0 , 50 , 75 and 100 % of recommended dose (RD = 200 kg ammonium sulphate / fed.) . It was added in two equal doses , after 20 and 30 days of planting . Also , before planting , at final soil preparation , all plots were fertilized by ordinary super phosphate (15.5 % P2O5) at rate of 200 kg / fed. + 50 kg / fed. of agricultural sulphur + 25 m^3 / fed. of compost . Also , all plots were received potassium fertilizer in the form of potassium sulphate (48 % K2O) at rate of 100 kg / fed. in two equal doses before the first and second irrigations in both two seasons . Pea (Master – B cv.) seeds were sown at 9^{th} and 11^{th} of October 2011 and 2012 in the tow seasons , respectively. A seeding rate of 50 kg seeds / fed., thus seeds were planted in hills 10 cm apart on the two sides of ridges and sown two seeds per hill and thinning treatment after 19 day from planting .

In both two seasons , at flowering stage (40 – 45 days from planting) , plant samples were successively taken randomly from three replicates of every treatments at single to determine the following parameters : vegetative growth parameters : plant height (cm) , number of leaves / plant , leaf area (cm²) , number of branches / plant , root length (cm) also the plant organs(roots , shoots and seeds) were separated and dried in electric oven at 70°C for 72 hrs then dry weights were determined in g / plant . Finally , of N fertilizer , the agronomic efficiency (g / kg) and relative change (%) of the obtained weights were calculated .

Where : The relative change (%) = { (Parameter value with magnetized water – Parameter value with non-magnetized water) / Parameter value with non-magnetized water } × 100 .

In both two seasons , at maturity stage of pods (after 75 days of planting) , the plants were harvested and shoots , roots and pods were separated to determine the following parameters : -

1-Yield : number of pods / plant , pod length (cm) , number of seeds / pod and weight of roots , shoots and seeds (g / plant) from fresh and dry weight and total yield (ton / fed.).

2- Yield components: some mineral content such as N , P and K (concentration and uptake) in both roots , shoots and seeds were determined using the methods described by Cottenie *et al.* (1982) and Page *et al.* (1982) . The crude protein was calculated by multiple the concentration of N (%) by 6.25 (A. O. A. C. , 1985) .

After plant harvesting , soil samples of each plot were taken separately at soil depth of 0 – 15 , 15 – 30 , 30 – 60 and 60 – 90 cm for some chemical analyses , i.e. the content of total soluble salts and the content of available N , P and K according to the methods described by Cottenie *et al.* (1982) and Page *et al.* (1982) .

All the obtained data from this study were exposed to proper statistical analysis of variance (ANOVA) by using Minitab computer program and least significant difference (L.S.D) at 0.05 probability level according to (Barbara and Brain , 1994) . Also , Duncan's multiple range was used for comparing means (Duncan , 1955) .

RESULTS AND DISCUSSION

The mechanism of the magnetically treated water activity in the soil is yet unclear . There is a possibility that the effect is physical , viz. through a change in the solvent capacity of water . An increase in that capacity can be the explanation of the differences detected while examining the soluble fraction of the soil , between the ordinary water and magnetically treated water . These differences varied between 50 percent to 300 percent (Harari and Lin , 1991) . There is a conjecture that water has a direct effect on physiological processes in the plant cells and it is possible that the reactions of the plant are of secondary importance . The direct influence is concentrated mainly on the composition or the mineral structure of the soil (Bresler , 1975) .

1 - Soil Salinity

The presented data in Table (3) show that , soil salinity measured as EC (dS m^{-1}) after harvesting was decreased at different soil depths with the treatments under study . The decreases of soil EC at all depths with different application rates of N fertilizer in the plots irrigated by magnetized water were more higher than that one irrigated by non-magnetized water . So , all values of relative changes of EC (RC , EC) as a percent of original soil EC values were negative and were more negative with magnetized water . Also , the decreases of soil EC with both magnetized and non-magnetized water were more clear and showed a high negative values of RC in the surface layers (0 – 15 cm) and reduced with the increase of soil depth . Takatshinko (1997) stated that , the possibility of using magnetized water to desalinate the soil is accounted for the enhanced dissolving capacity magnetized water , which has been registered repeatedly and who added that , magnetized water removed 50 to 80 % of soil Cl^{-} compared to a removed of 30 % by normal irrigation water . The found effect of magnetized water on soil desalination were reported and explained by Hilal and Hillal (2000 , a and b) ; Amiri and Dadkhah (2006) and Tai *et al.* (2008) .

Little decrease of soil EC (dS m^{-1}) was induced with the increase of added mineral N fertilizer (Table , 3) . Such this decrease was resulted from the little absorbed amounts of soluble ions (NO_3^{-} , PO_4^{3-} , $SO_4^{=}$, K^{+} , Ca^{++} ……..etc) by the grown plants . So , the high decrease of soil EC resulted from N fertilizer application was found in the surface layer (root zone) . In this respect , Ahmed (2005) and Gohar (2011) were gained similar results . This trend may by supported by RC (%) values of EC recorded in Table (3) . All values of RC EC were negative at different soil depth, but their were more negative at the high rates of added N specially in the deeper soil layers . Irrigation using magnetized water at different rates of added N , resulted in a more decrease of soil EC . These results were attributed to the activation and enhanced effect of this treatment on plant growth and its roots intensity and also on the improve of some physical , chemical and biological properties (Aladjadjiyan , 2002 and El – Fakhrani *et al.* , 2012) .

Table (3) : Soil EC (dSm^{-1}) and its vertical redistribution and relative change (RC) as a percentage (%) of the original soil value as affected by magnetized water under different levels of N fertilization (Mean values of the two growing seasons 2011 and 2012) .

Rate of added N fertilizer (% of RD*)	Parameters	Non- magnetized water					Magnetized water				
		0 –15 (cm)	15 – 30 (cm)	30 –60 (cm)	60 –90 (cm)	Mean	0 –15 (cm)	15 –30 (cm)	30 –60 (cm)	60 –90 (cm)	Mean
0	dSm^{-1}	1.40	1.59	1.75	1.83	1.64	1.22	1.48	1.68	1.75	1.53
	RC(%)	0.00	0.633	0.00	0.550	0.296	-12.86	-6.33	-4.00	-3.85	-6.76
50	dSm^{-1}	1.35	1.55	1.72	1.82	1.61	1.13	1.37	1.65	1.75	1.48
	RC(%)	-3.57	-1.90	-1.71	0.00	-1.80	-19.29	-13.29	-5.71	-3.85	-10.54
75	dSm^{-1}	1.32	1.53	1.72	1.80	1.59	1.02	1.28	1.60	1.73	1.41
	RC(%)	-5.71	-3.16	-1.71	-1.10	-2.92	-27.14	-18.99	-8.57	-4.95	-14.91
100	dSm^{-1}	1.30	1.50	1.70	1.75	1.56	0.95	1.20	1.55	1.72	1.36
	RC(%)	-7.14	-5.06	-2.86	-3.85	-4.73	-32.14	-24.05	-11.43	-5.49	-18.28
Mean	dSm^{-1}	1.34	1.54	1.72	1.80	1.60	1.08	1.33	1.62	1.74	1.44
	RC(%)	-4.29	-2.53	-1.72	-1.10	-2.29	-22.86	-15.82	-7.43	-4.40	-12.62

*RD = Recommended dose (200 kg ammonium sulphate / fed.) .

RC (%) = { (EC after harvesting - EC before planting) / EC before planting } × 100 .

Also , the obtained data in Table (3) revealed that application of irrigation water either magnetized or non-magnetized diminished the EC of the different soil layers, at varied addition of mineral N fertilizer. The highest reduction reached to be -7.14 % and -32.14 % compared to the control in 0 – 15 cm layer received the highest rate of N fertilization and irrigated with non-magnetized and magnetized water respectively . This may be attributed to the leaching effect of irrigation water , likewise enhancing root growth consequently nutrients absorption and reduction in EC . The facts which ought to be mentioned herein is that the linear diminishment in EC of the different soil layers was occurred with the incremental addition of N fertilizer (Table , 3) either with or with ought magnetized water . However the reduction of EC with magnetized water surpassed that one with non-magnetized water by more than three fold generally that refer to the beneficial effect of applied magnetized water on reclaiming soil salinity .

2 - Available N , P and K

The presented data in Table (4) show , that soil contents (mg kg^{-1}) of available N , P and K through different soil layers were varied widely from treatment to another . In all soil depths , irrigation using magnetized water resulted in a clear increase of soil content of available N , P and K where the high increase was found in the top soil layer. So , the high positive values of RC calculated as a percent (%) of original soil values of available N and P and K were found in the surface layer . These values increased positively with the increase of added N for available N , but their were lower positive effect for available P and K . These findings were resulted from the enhanced effect of both magnetized water on dissolving of many soil compounds specially soil organic matter. Also , these treatments were associated with the increase of biological activities in the soil (Takatshinko , 1997 ; Aladjadjiyan , 2002 and El – Fakhrani *et al.* , 2012) .

Individual applications of N fertilizers resulted in an increase of soil available N in all soil layers (Table , 4) . The high content (mg kg^{-1}) of available N and its RC was found in the surface layers (0 – 15 cm) in the experimental plots received 100 % RC of N fertilizer and irrigation with magnetized water . On the other hand , with non-magnetized and magnetized irrigation water , the soil content (mg kg^{-1}) of available P and K were decreased in the different soil layers as a result of added N mineral fertilizer . These decreases were attributed to the greater amounts of P and K absorbed by plants specially with high rates of added N fertilizer . In all treatments under study , the soil content of available N, P and K and their relative changes was decreased with the increase of soil depth . Maheshwari and Grewal (2009) and El – Fakhrani *et al.* (2012) obtained similar results , they recorded that the use of magnetically treated irrigation water increased soil available N , P and K . Magnetic treatment of water may be influencing desorption of P and K from soil adsorbed P on colloidal complex and thus increasing its availability to plants and thus resulting in an improved plant growth and productivity . Also , they argued that magnetic treatment of water slows down the movement of minerals probably due to the effect of acceleration of the crystallizations and precipitation processes of the solute minerals .

3-Effect of The Studied Treatments on Plant Growth

a - Vegetative growth characters .

The presented data in Table (5) show , plant height (cm) , number of both leaves and branches / plant , leaf area (cm^2) and root length (cm) of Pea plants and their relative changes (RC , %) as affected by irrigation using magnetized water compared with non-magnetized water under different levels of mineral N fertilization . All vegetative growth parameters under study were increased significantly as a result of irrigation using magnetized water (Table , 6). So , all values of RC (%) calculated for these parameters were positive . This trend was found in the two grown seasons with different levels of added N . In general , the

Table 4

Table 5

enhancement of plant growth under magnetic conditions appears to have been confirmed by many scientists. Similar finding were reported by Aladjadjiyan (2002) and Grewal and Maheshwari (2011) , they recorded that magnetic field stimulated root development and led to increase of the germination , fresh weight and shoot length of maize plants . Magnetic field beneficial effects on plants have been discussed for more than a decade . Also , they detected that magnetic field have a highly stimulating effect on cell multiplication , growth and development .

The calculated values of RC (%) for the estimated vegetative growth parameters show wide variations for these parameters to the studied treatments (Table , 5) . The highest values of RC (197.71 %) were found with number of branches / plant at second growth season and the lowest values (28.17 %) were recorded with plant height at first growth season , under different application of mineral N . In this respect, Hozayn and Abdul Qados (2010) and Abdul Qados and Hozayn (2010) obtained similar results .

In addition , the data in Tables (5 and 6) show a significant increases of the determined vegetative growth parameters as a result of the added mineral N . The found increases of the estimated growth parameters associated N fertilization in the plants irrigated by magnetized water were higher than those in the plants irrigated by non-magnetized water . With magnetized water , the highest value for the estimated growth parameters were associated the treatments of 75 % RD of mineral N , where the high values with non-magnetized water were recorded with the plants fertilized by 100 % RD of mineral N . These findings refer to that , the mineral N fertilizers efficiency was increased as a result of irrigation by magnetized water. That may be attributed to the enhancing effect of magnetic field on plant growth and improving soil properties consequently its content of available nutrients (Turker *et al.* , 2007 and Maheshwari and Grewal , 2009) .

b - Pods growth parameters .

The presented data in Tables (6 and 7) show the individual and combined effects of magnetized water and N fertilization on pod length (cm) , number of pods / plant and number of seeds / pod of Pea . All these parameters were increased significantly as a result of irrigation using magnetized water compared to the non-magnetized one (Table , 6) . This trend was found with different levels of added N fertilizer in the two growing seasons . These increases were varied from parameter to another as cleared from the calculated values of RC , % of these parameters . At the same treatment of N fertilizer , the highest value of RC , i.e. 63.15 % was found with number of pods / plant and the lowest value 13.04 % was recorded with pod length . This positive effect of magnetized water may be due to the enhanced effect of magnetic field on plant growth and improving soil properties specially the content of available nutrients (Hozayn and Abdul Qados , 2010 ; Abdul Qados and Hozayn , 2010 and El – Fakhrani *et al.*, 2012) .

Regarding to the effect of N fertilizer on the estimated growth parameters of pods presented in Tables (6 and 7) , noted that, the incremental addition of N with non-magnetized and magnetized irrigation water significantly increased the determined pods growth parameters , in the two growing seasons . Such these increases were resulted from the enhanced effect of N fertilization on plant growth which early recorded from many studies (Basak , 2006 and Tantawy *et al.* , 2011) . Except at rate of 100 % RD of added mineral N fertilization under irrigation using magnetized water , the values of RC % for the estimated pods growth parameters were increased positively with the increase of added mineral N . The decrease of pods growth parameters at rate of 100 % RD of N fertilizer compared with those associated the treatments of 75 % RD of N fertilizer reveals that , with magnetized water may be reduced the added dose of mineral N fertilizer up to 75 % of RD of Pea plant . This also means that , efficiency of mineral N fertilizers under irrigation by magnetized water was higher than that with non- magnetized water .

Table (6) : Statistical analysis (LSD at 0.05 level) of the studied variables of pea as affected the studied treatments .

The studied variables	Season (2011)			Season (2012)		
	A	B	AB	A	B	AB
Vegetative growth parameters						
Plant height	0.0749	0.1059	H.S.	0.0442	0.0625	H.S.
Number of leaves / plant	0.0551	0.0779	H.S.	0.0463	0.0655	H.S.
Leaf area	2.3852	3.3731	S.	1.2799	1.8088	S.
Number of branches/ plant	0.0417	0.0589	H.S.	0.0395	0.0559	H.S.
Root length	0.0497	0.0999	H.S.	0.0497	0.0703	H.S.
Pods growth parameters						
Pod length	1.4275	2.0188	N.S.	0.0605	0.0855	H.S.
Number of pods / plant	1.7965	2.5407	N.S.	0.0883	0.1248	H.S.
Number of seeds / pod	1.7805	2.5181	N.S.	0.0496	0.0701	H.S.
Fresh weight						
Roots	0.0807	0.1142	H.S.	0.0466	0.0659	H.S.
Shoots	106.21	150.20	N.S.	80.51	113.86	N.S.
Seeds	1.2945	1.8307	H.S.	0.8000	1.1313	H.S.
Dry weight						
Roots	0.0532	0.7520	H.S.	0.5260	0.0744	H.S.
Shoots	0.4490	0.6349	H.S.	0.1165	0.1648	H.S.
Seeds	0.6980	0.0988	H.S.	0.0411	0.5810	H.S.
Pods yield						
Green weight pods / plant	0.3605	0.5098	H.S.	16.063	22.760	N.S.
Early yield	0.0237	0.0335	H.S.	0.0509	0.0720	H.S.
Total yield	0.0438	0.0620	H.S.	0.0308	0.0435	H.S.
Nitrogen concentration						
Roots	0.0229	0.0324	H.S.	0.0272	0.0385	H.S.
Shoots	0.0331	0.0469	H.S.	0.0229	0.0324	H.S.
Seeds	0.0407	0.0576	H.S.	0.0365	0.0516	H.S.
Phosphorus concentration						
Roots	6.6353	9.3837	N.S.	0.0140	0.0198	H.S.
Shoots	0.0166	0.0234	N.S.	0.0147	0.0208	H.S.
Seeds	0.0264	0.0373	N.S.	0.0142	0.0201	H.S.
Potassium concentration						
Roots	0.0210	0.0297	H.S.	0.0162	0.0229	N.S.
Shoots	0.0153	0.0216	H.S.	0.0212	0.0300	H.S.
Seeds	0.0328	0.0404	H.S.	0.0215	0.0304	H.S.
Crude protein	0.2544	0.3600	H.S.	0.2281	0.3225	H.S.

A = Water treatments , B = Nitrogen fertilizer treatments and AB = Interaction .
H.S. = High significant , N.S. = Non significant and S. = Significant .

Table 7

c - Fresh and dry weights of plant origins .

The presented data in Tables (8 and 9) show that , both fresh and dry weights (g / plant) of roots , shoots and seeds of Pea plants were affected by magnetized water under different level of mineral N fertilization . These data show that , there are a significant increase of fresh and dry weights of the three origins as a result of irrigation by magnetized water compared with those found in the plants irrigated by non-magnetized water (Table , 6) . These findings were found in the two growing seasons under different levels of mineral N fertilization . Thus , all values of RC % calculated for both fresh and dry weights of the three origins were positive in the two grown seasons under different levels of added mineral N . From RC values may be noted that , there are a wide differences between the fresh and dry weights of Pea origins as affected by irrigation using magnetized water , where the high RC values were recorded with shoots followed by roots (fresh and dry weights) . At the same treatment of both added mineral N and magnetized water , RC values of fresh weight of Pea origins were higher than those of dry weight . Abdul Qados and Hozayn (2010) and Hozayn and Abdul Qados (2010) found that , using irrigation magnetized water induced positive significant effect on the percent of increase in seeds , straw and biological yield per plant of chick pea were 39.64 , 41.03 and 39.85 % , respectively compared with tap water . Magnetic water treatment could be used to enhance growth , chemical constituents and productivity of many plants (Selim , 2008 ; Abdul Qados and Hozayn , 2010 and El – Fakhrani *et al.* , 2012) .

Regarding to response of both fresh and dry weights of Pea origins to mineral N fertilization , the presented data in Tables (6 , 8 and 9) show a significant increase of fresh and dry weights as affected by raising the added N with non-magnetized water , but with magnetized water the found increases were achieved up to 75 % RD of N mineral fertilizer and a slight decrease at rate of 100 % RD . The increases of fresh and dry weights associated N fertilization were attributed to the beneficial effect of N fertilizer on plant growth , enzymes activity and biological activity (Basak , 2006) . These results are in agreement with those obtained by Tantawy *et al.* (2011) . On the other hand , the decreases of both fresh and dry weights of Pea plants origins irrigated by magnetized water at high rate of added N means that , irrigation using magnetized water increased mineral N fertilizer efficiency . So , may be obtained on maximum fresh and dry weights of plant origins using only 75 % RD of mineral N fertilizer . These findings may be played a major role in the reduction of environment pollution by different N forms . These results may be supported by calculated values of RC (%) which increased positively with the increase of added N (Tables , 8 and 9) .

The weight (g) produced from each unit (kg) of added N namely agronomic efficiency (AE) and recorded in Tables (8 and 9) show that , this efficiency in the different plant origins fresh and dry weights in the plants irrigated by magnetized water was higher than that one irrigated by non-magnetized water . This trend was detected with different levels of added N in the two grown seasons . These results are in harmony with the soil content of available N affected by irrigation using magnetized water (53.75 mg kg^{-1}) and also with this water treatment on improved physical , chemical and biological soil properties (Hilal and Hillal , 2000 a and b ; Tai *et al.* , 2008 and El – Fakhrani *et al.* , 2012) .

d - Green pods yield .

Green pods (g / plant) , early pods yield (ton / fed.) and total pods yield (ton / fed.) and its relative changes of Pea as affected by irrigation using magnetized water and added level of mineral N fertilizer recorded in Table (10) show that , in the two growing seasons , magnetized water significantly augmented Pea yield expressed as green pods weight , early pods yield and total pods yield (Table , 6) . At the same rate of added mineral N , these responses were varied

Table 8

Table 9

Table 10

from parameter to another as cleared from the values of RC (%) calculated for these parameters yield . Selim (2008) and El – Fakhrani *et al.* (2012) attributed such these increases to the enhanced effect of magnetic field on nutrients availability , biological activity and improved rhizosphere area condition .

Increasing level of added mineral fertilizer in two growing seasons with both magnetized and non-magnetized water significantly increased weight of green pods (g / plant) , early pods yield (ton / fed.) and total pods yield (ton / fed.) of Pea plants . These increases in the plants irrigated by magnetized water were higher than those irrigated by non-magnetized water (Table , 10) . Yusron and Phillips (1997) and Tantawy *et al.* (2011) showed a positive effect of mineral N fertilizer on plant growth . The calculated values of RC (%) for the three parameters yield were positive and increased with the increase of added N , except at rate of 100 % RD of added N fertilizer which gave RC lower than that at 75 % RD N fertilizer . The latter result show the ability reduce of added N to 75 % of its recommended dose (RD) .

In addition , the data in Tables (8 and 9) show the positive effect of magnetic treatment of irrigation water on agronomic efficiency (AE) of the applied mineral N fertilizer , where AE values for the three yield parameters in the plants irrigated by magnetized water were higher than those in the plants irrigated by non-magnetized water.

e - The content of macronutrients .

The recorded data in Tables (11 and 12) show N , P and K concentration (%) and its relative change (RC %) and also their uptake (mg / plant) by Pea plants in 2011 and 2012 seasons as affected by irrigation using magnetized water under different application rates of mineral N fertilization . With different rates of added N, irrigation using magnetized water significantly increased both concentration (Table , 6) and uptake of N , P and K in roots , shoots and seeds of Pea in the two grown seasons . The high concentration of N , P and K in the two growing seasons was found with seeds and the lowest one was found with roots . On the other hand , the highest uptake of these three nutrients was found with shoots followed by that with seeds . So , all values of RC for N , P and K concentration were positive . For different origins of Pea plant the highest values of RC were recorded with P followed by K . Previous studies reported that magnetic field led to a positive effect on the number of flowers and total yield (Podlesny *et al.* , 2005) , seeds germination percentage and nutrients uptake (Esitken and Turan , 2003) . In addition , application of a magnetic field to irrigation was shown to increase plant nutrients content (El – Fakhrani *et al.* , 2012) . Finally , Grewal and Maheshwari (2011) showed that magnetic treatment of irrigation water led to a significant increase in shoots dry weight (25 % for snow pea and 20 % for chick pea) and contents of N , K , Ca , Mg , S , Na , Zn , Fe , and Mn in both seedling varieties compared with control seedlings .

Increasing level of added mineral N fertilizer was associated by increase of N , P and K concentration (%) and uptake (mg kg^{-1}) by both roots , shoots and seeds of Pea plants in the two growing seasons with either of non-magnetized or magnetized water (Tables , 11 and 12) . The found increase of N , P and K content in the three origins at the same level of added N in the plants irrigated by magnetized water was higher than those found in the plants irrigated by non-magnetized water . Also , the high concentrations of these three nutrients were found in the seeds followed by shoots . On the other hand , the highest values of N , P and K uptake were found with shoots and the lowest one was found with roots . These findings were in agreement with those obtained by Tantawy *et al.* (2011) and El – Fakhrani *et al.* (2012).

f - Crude protein content .

The presented data in Table (13) show that , seeds content (%) of crude protein in the plants irrigated by magnetized water was increased significantly compared with that

Table 11

Table 12

Table (13): Seeds of Pea content (%) of crude protein and its relative change (RC, %) as affected by magnetized water and mineral nitrogen fertilization in 2011 and 2012 seasons .

Rate of added N Fertilizer (% of RD*)	Season (2011)				Season (2012)			
	Non-magnetized water	Magnetized water	Mean	RC (%)	Non-magnetized water	Magnetized water	Mean	RC (%)
0	18.44	21.38	19.91	15.94	18.25	21.25	19.75	16.44
50	20.00	22.50	21.25	12.50	20.19	22.81	21.50	12.98
75	21.88	24.50	23.19	11.97	21.88	24.69	23.29	12.84
100	23.00	25.63	24.32	11.43	23.00	25.63	24.32	11.43
Mean	20.83	23.50	22.17	12.96	20.83	23.52	22.22	13.42

*RD = Recommended dose (200 kg ammonium sulphate / fed.) .

found under irrigation by non-magnetized water . These findings were found in the two growing seasons with all levels of added N fertilizer . Thus , all values of RC (%) of crude protein content were positive . Also , similar positive effect and significant increase in the seeds content of crude protein as a result of increase of added mineral N fertilizer . These findings were in harmony with the results of seeds content (%) of N . These results reveals that , irrigation using magnetized water and fertilization by mineral N individually or in combination resulted in an improve quality of Pea seeds by increasing its content of crude protein .

REFERENCES

Abdul Qados, Amira M. and M. Hozayn (2010). Magnetic water technology , a novel tool to increase growth , yield and chemical constituents of lentil (*Lens esculent*) under greenhouse condition . J. Agric & Environ. Sci. 7 (4) 457 – 462.

Ahmed, Hoda R. M. (2005). Studies on some salt – affected soils in Egypt . Ph. D. Thesis , Fac. of Agric. , Minufiya Univ., Egypt .

Aladjadjiyan, A. (2002). Study of the influence of magnetic field on some Biological characteristics of Zea mais . J. of Central Europe Agriculture, 3(2):89–94.

Amiri, M. C. and A. A. Dadkhah (2006): On reduction in the surface tension of water due to magnetic treatment . Colloids Surf A : Physicochemical Eng Aspects, 278: 252 – 255 .

A. O. A. C. (1985): Association of Official Agriculture Chemists. Official Methods of Analysis 14th Ed. Washington, D. C.

Barbara, F. R. and L. J. Brain (1994): "Minitab Hand Book " . Duxbury Press. An Imprint of Wad Swarthy Publish. Comp. Belonont California .

Basak, R. K. (2006): " Fertilizers " . Kalyani Publishers, Ludhiana – New Delhi Noida (U. P.) Hyderabad – Chennai – Calcutta – Cuttack .

Bresler, E. (1975): Two – dimensional transport of solutes during non - steady infiltration from a trickle source . Soil Sci. Soc. Amer. Proc. 39 , 604 – 611 .

Celik, O., C. A. Atak and A. Rzakulieva (2008): Stimulation of rapid regeneration by a magnetic field in paulownia node cultures . J. of Central Europe. Agric. , 9 (2) 297 – 303 .

Cottenie, A., M. Verloo, L. Kiekens, G. Velghe and R. Camerlynck (1982): "Chemical Analysis of Plants and Soils " . Laboratory of Analytical and Agrochemistry, State Univ., Ghent, Belgium .

Duncan, D. B. (1955): Multiple Range and Multiple F-test Biometrics , II : 1 – 42.

El – Dakkak, A. A. A., N. M. Kandeel, A. M. Damarany and G. A. Zayed (2005): Estimation of the components of the genetic variation using triple test cross analysis in peas (*Pisum sativum L.*) under upper Egypt conditions . Ph. D. Thesis , Fac. of Agric. , Assiut Univ. , Egypt .

El – Fakhrani, Y. M., S. S. Mabrouk , M. H. Hilal, A. I. Mohamed and B. M. Ebead (2012): Effectiveness of leaching with magnetized irrigation water in salt removal from sandy soil and availability of some nutrients. 10th International Conference of Egyptian Soil Sci., Nov. 5 – 8 , 2012 , Ameria , Alexandria , Egypt . (under impress) .

Esitken, A. and M. Turan (2003): Alternating magnetic field effects on yield and plant nutrient element composition of strawberry (*Fragaria ananassa cv. Camarosa*) . Act Agriculture Scandinavian. Section B , Soil and Plant 54 , 135–139 .

Gohar-Heba, M. A.M. (2011): Effect of some plant residues on soil properties and plant growth in newly reclaimed soils . M. Sc. Thesis , Fac. of Agric. , Minufiya Univ. , Egypt .

Grewal, S. H. and B. L. Maheshwari (2011): Magnetic treatment of irrigation water and snow pea and chick pea seeds enhances early growth and nutrient contents of seedlings . Bioelectromagnetics , 32 (1) 58 – 65 .

Harari , M. and I. Lin (1991): Response of melons to magnetically – treated water . Water and Irrigation Review , 9 : 4 – 7 .

Hilal, M. H. and M. M. Hillal (2000 a): Application of magnetic technologies in desert agriculture . I – Seed germination and seedling emergence of some crops in a saline calcareous soil . Egypt J. Soil Sci., 40 (3) 413 – 421 .

Hilal, M. H. and M. M. Hillal (2000 b): Application of magnetic technologies in desert agriculture . II – Effect of magnetic treatments of irrigation water on salt distribution in olive and citrus field and induced changes of ionic balance in soil and plant . Egypt J. Soil Sci., 40 (3) 423 – 435 .

Hozayn, M. and Amira M. Abdul Qados (2010): Irrigation with magnetized water enhances growth , chemical constituent and yield of chick pea (*Cicer arietinum L.)* . Agric. Biol. J. of North America. 1 (4) 671 – 676 .

Kim, H. T. (1996): " Soil Sampling, Preparation and Analysis " . Marcel Dekker Inc. , New York , p . 391 .

Maheshwari, B. L. and S.H.Grewal (2009): Magnetic treatment of irrigation water : Its effects on vegetable crop yield and water productivity . Agric. Water Manage , 96 : 1229 – 1236 .

Page, A. L., R. H. Miller and D . R . Keeney (1982): " Methods of Soil Analysis " . II . Chemical and Microbiogical Properties . 2nd Ed . Madison , Wisconsin , U . S . A .

Podlesny, J., S. Pietruszewski and A. Podlesna (2005): Influence of magnetic stimulation of seed on the formation of morphological features and yielding of the pea International Agro physics , 19 : 61 – 68 .

Selim-Dalia , A. F. H. (2008): Response of some economic plants to magnetized water supply . M. Sc. Thesis , Fac. of Agric. , Minufiya Univ. , Egypt .

Shabrangi, A. and A. Majd (2009): Effect of magnetic fields on growth and antioxidant systems in agricultural plants . PIERS Proceeding , Beijing , China , March , 23 – 27 .

Tai, C. Y., C. K. Wu and M. C. Chang (2008): Effect of magnetic field on the crystallization of CaCO3 using permanent magnets . Chem. Engin. Sci. 63 : 5606 – 5612 .

Takatshinko, Y. (1997): Hydro magnetic systems and their role in creating micro climate . International Symposium on Sustainable Management of Salt Affected Soils , Cairo , Egypt , 22 - 28 Sept. (C. F. El – Fakhrani et al. , 2012).

Tantawy- Manal, F., A. Kh. Amer and Kadria M. El – Azab (2011): Effect of fertilization with bio – and mineral – N on yield and yield component of rice grown on a clayey soil . Minufiya J. Agric. Res. , 36 (3) 757 – 774 .

Turker, M., C. Temirci , P. Battal and M. E. Erez (2007): The effect of an artificial and static magnetic field on plant growth, chlorophyll and phytohormone levels in maize and sunflower plants . Phyton Ann. Rei Bot. 46 : 271 – 284 .

Yusron, M. and I. R. Phillips (1997): Nitrogen leaching from urea and ammonium fertilizers under uncropped and cotton cropped conditions. Indonesian J. Crop Sci. 12 (1) 23 – 33 .

تأثير ماء الري الممغنط علي كفاءة التسميد النيتروجيني و تيسر المغذيات و إنتاجية نبات البسلة

سالي عبد الرازق ميدان[١] ، منال فتحي طنطاوي[٢]

[١] قسم البساتين – كلية الزراعة – جامعة المنوفية – مصر

[٢] معهد بحوث الأراضي و المياه و البيئة – مركز البحوث الزراعية – الجيزة – مصر

الملخص العربي

أجريت تجربة حقلية علي الأرض الرسوبية الطينية بالمزرعة البحثية بكلية الزراعة – جامعة المنوفية بشبين الكوم – مصر , خلال موسمي نمو شتويين متتاليين (٢٠١١ و ٢٠١٢) علي نبات البسلة صنف ماستر ب وذلك لتقدير الأثر الفردي والمشترك لكل من ماء الري الممغنط ومستويات الإضافة المختلفة للسماد المعدني النيتروجيني (كبريتات الأمونيوم) والتي تمثل صفر , ٥٠ , ٧٥ و ١٠٠٪ من الجرعة الموصي بها والتي تساوي ٢٠٠ كجم كبريتات الأمونيوم / فدان , علي ملوحة الأرض ومحتواها من النيتروجين , الفوسفور والبوتاسيوم الميسر وكذلك علي نمو وإنتاجية نبات البسلة ومحتواها من النيتروجين , الفوسفور والبوتاسيوم . ولقد صممت التجربة في نظام قطاع تام العشوائية بثلاث مكررات .

ولقد أظهرت النتائج المتحصل عليها نقصا في ملوحة الأرض وزيادة في محتواها من النيتروجين , الفوسفور والبوتاسيوم الميسر في الطبقات المختلفة للأرض المروية بالماء الممغنط مقارنة بما وجد مع الماء الغير ممغنط . في حين قد تباين تأثير التسميد النيتروجيني المعدني علي صفات الأرض تحت الدراسة , كما أدي الري بالماء الممغنط إلي زيادة معنوية في جميع مقاييس النمو والتي تشمل قيم كل من طول النبات وعدد الأفرع لكل نبات وعدد الأوراق لكل نبات ومساحة الورقة وطول الجذر وأيضا عدد القرون لكل نبات وطول القرن وعدد البذور في كل قرن وذلك مقارنة بمقاييس النمو المتحصل عليها مع الماء الغير ممغنط وذلك عند نفس مستوي التسميد النيتروجيني المعدني. وكذلك فقد أوضحت هذه القياسات زيادة معنوية مع زيادة المضاف من السماد النيتروجيني المعدني.

بالإضافة إلي ذلك فقد أدي الري بالماء الممغنط إلي زيادة معنوية في كل من الوزن الطازج والجاف (جم / نبات) للجذور , السيقان والبذور والوزن الطازج للقرون وأيضا زيادة كل من المحصول الأولي (الجمعة الأولي) والمحصول الكلي (طن / فدان) , وقد أظهرت إضافات السماد النيتروجيني المعدني نتائج مماثلة . كما إزداد محتوي الجذور , السيقان والبذور (٪ و مجم / نبات) من كل من النيتروجين , الفوسفور والبوتاسيوم بزيادة المضاف من السماد النيتروجيني المعدني وخاصة مع النباتات المروية بالماء الممغنط . وقد أوضحت النتائج كذلك أنه أمكن الحصول علي أعلي محصول أولي وأيضا المحصول الكلي لنبات البسلة بإضافة ٧٥٪ من الجرعة الموصي بها من السماد النيتروجيني المعدني مع إستخدام الماء الممغنط في الري .

Table (13) : Seeds of snap bean content (%) of crude protein and its relative change (RC , %) as affected by magnetized water and mineral nitrogen fertilization in 2011 and 2012 seasons .

Rate of added N fertilizer (% of RD*)	Season (2011)				Season (2012)			
	Non-magnetized water	Magnetized water	Mean	RC (%)	Non-magnetized water	Magnetized water	Mean	RC (%)
0	18.44	21.38	19.91	15.94	18.25	21.25	19.75	16.44

50	20.00	22.50	21.25	12.50	20.19	22.81	21.50	12.98
75	21.88	24.50	23.19	11.97	21.88	24.69	23.29	12.84
100	23.00	25.63	24.32	11.43	23.00	25.63	24.32	11.43
Mean	20.83	23.50	22.17	12.96	20.83	23.52	22.22	13.42

*RD = Recommended dose (200 kg ammonium sulphate / fed.) .

.

Table (5) : Some growth characters of snap bean plants and its relative change (RC , %) as affected by the studied treatments (mean values of two growing seasons)

Rate of added N Fertilizer (% of RD)	Non-magnetized water					Magnetized water					Means					Relative change (RC , %)				
	Plant height (cm)	No. of leaves / plant	Leaf area (cm^2)	No. of branches / plant	Root length (cm)	Plant height (cm)	No. of leaves / plant	Leaf area (cm^2)	No. of branches / plant	Root length (cm)	Plant height (cm)	No. of leaves / plant	Leaf area (cm^2)	No. of branches / plant	Root length (cm)	Plant height (cm)	No. of leaves / plant	Leaf area (cm^2)	No. of branches / plant	Root length (cm)
First season (2011)																				
0	40.83^{c}	15.25^{c}	173.80^{d}	2.00^{d}	6.22^{d}	65.60^{c}	22.85^{d}	299.25^{c}	4.00^{d}	15.22^{c}	53.22^{D}	19.05^{D}	236.53^{C}	3.00^{B}	10.72^{C}	60.67	49.84	72.18	100.00	144.69
50	52.62^{b}	20.50^{b}	180.32^{c}	2.80^{c}	8.42^{c}	83.45^{b}	30.20^{c}	313.84^{a}	7.58^{a}	21.60^{a}	70.54^{C}	25.35^{C}	247.05^{B}	5.19^{A}	15.01^{B}	58.59	47.32	74.05	170.71	156.53
75	59.32^{b}	21.35^{b}	185.45^{b}	3.00^{b}	9.38^{b}	87.15^{a}	33.28^{b}	311.92^{b}	7.00^{b}	20.45^{b}	73.24^{B}	27.32^{B}	248.69^{B}	5.00^{A}	14.92^{B}	46.92	55.88	68.20	133.33	118.02
100	66.50^{a}	21.82^{a}	188.72^{a}	3.75^{a}	11.00^{a}	85.23^{ab}	38.00^{a}	310.92^{b}	6.52^{c}	20.00^{b}	75.85^{A}	29.91^{A}	249.82^{A}	5.14^{A}	15.50^{A}	28.17	74.15	64.75	73.87	81.82
Mean	54.82^{B}	19.73^{B}	182.07^{B}	2.89^{B}	8.76^{D}	80.36^{A}	31.08^{A}	308.98^{A}	6.28^{A}	19.32^{A}	68.21	25.41	245.52	4.58	14.04	48.59	56.80	69.80	119.48	125.27
Second season (2012)																				
0	43.05^{d}	15.47^{d}	208.56^{d}	2.36^{d}	7.74^{d}	67.82^{d}	25.07^{c}	354.10^{b}	4.22^{d}	16.42^{b}	55.44^{C}	20.27^{C}	281.33^{B}	3.29^{A}	12.08^{C}	57.54	62.06	69.78	78.81	112.14
50	50.84^{c}	22.02^{c}	216.38^{c}	2.62^{b}	9.64^{c}	90.67^{a}	42.92^{a}	376.01^{a}	7.80^{a}	22.82^{a}	70.76^{B}	32.47^{B}	296.20^{A}	5.21^{B}	16.23^{B}	78.34	94.91	73.77	197.71	136.72
75	61.54^{b}	26.95^{ab}	222.45^{b}	3.25^{c}	10.60^{b}	89.37^{ab}	42.20^{a}	374.30^{a}	7.20^{b}	22.67^{a}	75.66^{A}	34.58^{A}	298.38^{A}	5.23^{B}	16.64^{B}	45.22	56.59	45.79	121.54	113.87
100	64.72^{a}	27.04^{a}	226.46^{a}	3.95^{a}	12.20^{a}	87.45^{c}	40.22^{b}	373.10^{a}	6.14^{c}	22.03^{a}	79.09^{A}	33.63^{B}	299.78^{A}	5.06^{C}	17.12^{A}	35.12	48.74	64.75	55.44	80.57
Mean	55.04^{B}	22.87^{B}	218.46^{B}	3.05^{B}	10.05^{B}	83.83^{A}	37.60^{A}	369.38^{A}	6.34^{B}	20.99^{A}	70.22	30.24	293.92	4.70	15.52	54.06	65.58	63.52	113.38	110.83
Mean	54.93	21.30	200.27	2.97	9.41	82.10	34.34	339.18	6.31	20.16	69.53	27.83	269.72	4.64	14.78	51.33	61.19	66.66	116.43	118.05

Table (7) : Pods growth parameters of snap bean plants and their relative change (RC ,%) as affected by magnetized water under different levels of mineral N fertilization during two growing seasons (2011 and 2012) .

Rate of added N Fertilizer (% of RD)	Non-magnetized water			Magnetized water			Means			Relative change (RC , %)		
	Pod length (cm)	No. of pods / plant	No. of seeds / pod	Pod length (cm)	No. of pods / plant	No. of seeds / pod	Pod length (cm)	No. of pods / plant	No. of seeds / pod	Pod length (cm)	No. of pods / plant	No. of seeds / pod
	First season (2011)											
0	7.30 ^{bc}	20.70	5.20 ^{d}	9.80	31.20 ^{c}	8.00 ^{cd}	8.55 ^{C}	25.95 ^{C}	6.60 ^{A}	34.25	50.72	53.85
50	8.00 ^{b}	23.23	6.30 ^{c}	12.10	37.80 ^{b}	9.00 ^{c}	10.05 ^{B}	30.52 ^{B}	7.65 ^{C}	51.25	62.72	42.86
75	8.97 ^{b}	25.00	7.03 ^{bc}	12.40	40.06 ^{a}	10.00 ^{a}	10.69 ^{B}	32.53 ^{B}	8.52 ^{B}	38.24	60.24	42.25
100	10.00 ^{a}	25.90	7.85 ^{b}	11.80	38.95 ^{b}	9.67 ^{b}	10.90 ^{A}	32.43 ^{A}	8.76 ^{B}	18.00	50.39	23.18
Mean	**8.57 ^{B}**	**23.71 ^{B}**	**6.60 ^{B}**	**11.53 ^{A}**	**37.00 ^{A}**	**9.17 ^{A}**	**10.05**	**30.36**	**7.88**	**35.44**	**56.02**	**40.54**
	Second season (2012)											
0	8.50 ^{d}	22.10 ^{c}	5.09 ^{d}	11.00 ^{c}	32.60 ^{c}	7.86 ^{c}	9.75 ^{C}	27.35 ^{C}	6.48 ^{D}	29.41	47.51	54.42
50	9.20 ^{c}	24.63 ^{a}	6.22 ^{c}	13.32 ^{a}	39.20 ^{b}	8.89 ^{a}	11.26 ^{B}	31.92 ^{A}	7.56 ^{C}	44.78	59.16	42.93
75	10.17 ^{b}	25.40 ^{c}	6.92 ^{b}	13.60 ^{a}	41.44 ^{a}	9.88 ^{a}	11.89 ^{B}	33.42 ^{B}	8.40 ^{AB}	33.73	63.15	42.77
100	11.50 ^{a}	26.65 ^{b}	7.74 ^{a}	13.00 ^{b}	40.35 ^{b}	9.56 ^{b}	12.25 ^{A}	33.50 ^{B}	8.65 ^{A}	13.04	51.41	23.51
Mean	**9.84 ^{B}**	**24.70 ^{B}**	**6.49 ^{B}**	**12.73 ^{A}**	**38.40 ^{A}**	**9.05 ^{A}**	**11.29**	**31.55**	**7.77**	**30.24**	**55.31**	**40.91**
Mean	**9.21**	**24.21**	**6.55**	**12.13**	**37.70**	**9.11**	**10.67**	**30.96**	**7.83**	**32.84**	**55.67**	**40.73**

Table (8) : Fresh weight (g / plant) of snap bean plants (roots , shoots and seeds) and its relative change (RC , %) and also agronomic efficiency (AE) of mineral N fertilizer (g / kg) under different levels of N fertilization and irrigation with magnetized water during two growing seasons (2011 and 2012) .

Rate of added N Fertilizer (% of RD)	Non-magnetized water						Magnetized water						Mean values			Relative change (RC , %)		
	Roots		Shoots		Seeds		Roots		Shoots		Seeds		Roots (g / plant	Shoots (g / plant)	Seeds (g / plant)	Roots	Shoots	Seeds
	g / plant	AE (g/kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)						
	First season (2011)																	
0	10.95 ^{d}		257.45 ^{c}		80.50 ^{c}		20.10 ^{c}		611.43 ^{c}		122.25 ^{d}		15.53 ^{C}	434.44 ^{C}	101.38 ^{C}	83.56	137.49	51.86
50	15.12 ^{c}	0.042	350.60 ^{b}	0.932	92.70 ^{b}	0.122	28.05 ^{a}	0.080	772.34 ^{a}	1.61	145.13 ^{c}	0.229	21.59 ^{B}	561.47 ^{A}	118.92 ^{B}	85.52	120.29	56.56
75	16.20 ^{b}	0.035	377.22 ^{b}	0.800	100.65 ^{a}	0.134	26.03 ^{b}	0.040	751.12 ^{b}	0.930	157.80 ^{a}	0.237	21.12 ^{B}	564.17 ^{A}	129.23 ^{A}	60.68	99.12	56.78
100	17.75 ^{a}	0.034	433.25 ^{a}	0.880	103.78 ^{a}	0.116	25.98 ^{b}	0.029	708.61 ^{d}	0.486	150.30 ^{b}	0.140	21.87 ^{A}	570.93 ^{B}	127.04 ^{A}	46.37	63.56	44.83
Mean	15.01 ^{B}	0.037	354.63 ^{B}	0.870	94.41 ^{A}	0.124	25.04 ^{A}	0.050	710.88 ^{A}	1.01	143.87 ^{A}	0.202	20.03	532.75	119.14	69.03	105.12	52.51
	Second season (2012)																	
0	9.07 ^{d}		228.45 ^{b}		83.44 ^{d}		20.22 ^{b}		580.43 ^{c}		121.50 ^{a}		14.65 ^{C}	404.44 ^{C}	102.47 ^{B}	122.93	154.07	45.61
50	13.24 ^{c}	0.042	321.60 ^{b}	0.930	93.50 ^{c}	0.101	28.14 ^{a}	0.079	741.32 ^{b}	1.61	147.20 ^{c}	0.257	20.69 ^{B}	531.46 ^{B}	120.35 ^{C}	112.54	130.51	57.43
75	14.32 ^{b}	0.035	348.22 ^{c}	0.800	100.10 ^{b}	0.111	28.15 ^{a}	0.053	720.10 ^{a}	0.930	159.15 ^{b}	0.251	21.24 ^{B}	534.16 ^{B}	129.63 ^{B}	96.58	106.79	58.99
100	15.87 ^{a}	0.034	399.45 ^{a}	0.855	110.15 ^{a}	0.134	28.10 ^{a}	0.039	677.59 ^{b}	0.486	151.17 ^{b}	0.198	21.99 ^{A}	538.52 ^{A}	130.66 ^{A}	77.06	69.63	37.24
Mean	13.13 ^{B}	0.037	324.43 ^{B}	0.860	96.80	0.115	26.15 ^{A}	0.057	679.86 ^{A}	1.01	144.76 ^{A}	0.235	19.64	502.15	120.78	102.28	115.25	49.82
Mean	14.07	0.037	339.53	0.865	95.61	0.120	25.60	0.053	695.37	1.01	144.32	0.219	19.84	517.45	119.96	85.66	110.19	51.17

Table (9) : Dry weight (g / plant) of snap bean plants (roots , shoots and seeds) and its relative change (RC , %) and also agronomic efficiency (AE) of mineral N fertilizer (g / kg) under different levels of N fertilization and irrigation with magnetized water during two growing seasons (2011 and 2012) .

Rate of added N Fertilizer (% of RD)	Non-magnetized water						Magnetized water						Mean values			Relative change (RC , %)		
	Roots		Shoots		Seeds		Roots		Shoots		Seeds		Roots (g / plant)	Shoots (g / plant)	Seeds (g / plant)	Roots	Shoots	Seeds
	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)	g / plant	AE (g / kg)						
	First season (2011)																	
0	2.00^{b}		45.04^{c}		20.15^{d}		4.00^{c}		82.38^{c}		30.18^{d}		3.00^{C}	63.71^{C}	25.17^{C}	100.00	82.90	49.78
50	4.36^{b}	0.024	60.32^{b}	0.153	23.32^{c}	0.032	6.18^{a}	0.022	112.71^{a}	0.303	35.20^{c}	0.050	5.27^{B}	86.52^{A}	29.26^{B}	41.74	86.85	50.94
75	4.56^{b}	0.017	61.60^{b}	0.110	26.80^{b}	0.044	6.16^{a}	0.014	110.96^{a}	0.191	38.35^{a}	0.055	5.36^{B}	86.28^{A}	32.58^{A}	35.09	80.13	43.10
100	5.06^{a}	0.015	66.43^{a}	0.107	27.45^{a}	0.037	5.83^{b}	0.009	100.70^{b}	0.092	37.50^{b}	0.037	5.45^{A}	83.57^{B}	32.48^{A}	15.22	51.59	36.61
Mean	4.00^{B}	0.019	58.35^{B}	0.123	24.43^{B}	0.038	5.54^{A}	0.015	101.69^{A}	0.195	35.31^{A}	0.047	4.77	80.02	29.87	48.01	75.37	45.11
	Second season (2012)																	
0	2.25^{c}		41.63^{c}		20.22^{b}		3.25^{c}		78.96^{c}		30.25^{b}		2.75^{C}	60.30^{C}	25.24^{B}	44.44	89.67	49.60
50	4.11^{b}	0.019	56.90^{b}	0.153	23.10^{b}	0.029	5.43^{a}	0.022	109.49^{a}	0.305	35.10^{b}	0.049	4.77^{B}	83.20^{A}	29.10^{B}	32.12	92.43	51.95
75	4.46^{b}	0.015	58.18^{b}	0.110	26.00^{a}	0.039	5.41^{a}	0.014	107.54^{b}	0.191	38.50^{a}	0.055	4.94^{A}	82.86^{B}	32.25^{A}	21.30	84.84	48.08
100	4.58^{a}	0.012	61.30^{a}	0.098	27.25^{a}	0.035	5.31^{b}	0.010	104.58^{b}	0.128	37.35^{a}	0.036	4.95^{A}	82.94^{B}	32.30^{A}	15.94	70.60	37.06
Mean	3.85^{B}	0.015	54.50^{B}	0.121	24.12^{B}	0.034	4.85^{A}	0.016	100.14^{A}	0.208	35.30^{A}	0.046	4.35	77.33	29.72	28.45	84.39	46.67
Mean	3.93	0.017	56.43	0.122	24.28	0.036	5.20	0.015	100.92	0.202	35.31	0.047	4.56	78.68	29.80	38.23	79.88	45.89

Table (10) : Green pods weight (g / plant) , early yield and total yield (ton / fed.) of snap bean plants and its relative change (RC , %) and also agronomic efficiency (AE) of mineral N as affected by magnetized water under different levels of N fertilizer during two growing seasons (2011 and 2012) .

Rate of added N Fertilizer (% of RD)	Non-magnetized water						Magnetized water						Mean values			RC (%)		
	Green pods		Early yield		Total yield		Green pods		Early yield		Total yield		Green pods weight (g / plant)	Early yield (ton / fed.)	Total yield (ton/fed.)	Green pods weight	Early yield	Total yield
	g / plant	AE (g /kg)	Ton / fed.	AE (g /kg)	Ton / fed.	AE (kg/kg)	g / plant	AE (g /kg)	Ton / fed.	AE (kg/kg)	Ton / fed.	AE (kg/kg)						
	First season (2011)																	
0	**70.62^{c}**		**0.00^{d}**		**3.28^{d}**		**96.60^{c}**		**2.26^{c}**		**6.26^{c}**		**83.61^{C}**	**1.13^{C}**	**4.77^{C}**	**36.79**	**0.00**	**90.85**
50	**77.79^{b}**	**0.072**	**1.00^{c}**	**0.010**	**4.81^{c}**	**0.015**	**100.20^{b}**	**0.036**	**3.10^{b}**	**0.008**	**7.99^{b}**	**0.017**	**88.99^{B}**	**2.05^{B}**	**6.40^{B}**	**28.81**	**210.00**	**66.11**
75	**80.78^{a}**	**0.068**	**1.95^{b}**	**0.013**	**5.04^{b}**	**0.012**	**105.02^{a}**	**0.056**	**3.31^{a}**	**0.007**	**8.46^{a}**	**0.015**	**92.90^{A}**	**2.63^{A}**	**6.75^{A}**	**30.01**	**69.74**	**67.86**
100	**84.15^{a}**	**0.068**	**2.20^{a}**	**0.011**	**5.76^{a}**	**0.012**	**103.38^{a}**	**0.034**	**3.27^{a}**	**0.005**	**8.23^{a}**	**0.010**	**93.77^{A}**	**2.74^{A}**	**7.00^{A}**	**22.85**	**48.64**	**42.88**
Mean	**78.34^{B}**	**0.069**	**1.29^{B}**	**0.011**	**4.72^{B}**	**0.013**	**101.30^{A}**	**0.042**	**2.99^{A}**	**0.006**	**7.74^{A}**	**0.014**	**89.82**	**2.14**	**6.23**	**29.62**	**82.10**	**66.93**
	Second season (2012)																	
0	**71.77**		**0.00^{d}**		**3.08^{c}**		**97.75^{b}**		**2.10^{c}**		**5.90^{d}**		**84.76**	**1.05^{C}**	**4.49^{C}**	**36.20**	**0.00**	**91.56**
50	**78.94**	**0.072**	**1.00^{c}**	**0.010**	**5.03^{b}**	**0.020**	**101.35^{c}**	**0.036**	**2.96^{b}**	**0.008**	**7.49^{c}**	**0.016**	**90.15**	**1.98^{B}**	**6.26^{B}**	**28.39**	**196.00**	**48.91**
75	**81.93**	**0.068**	**1.85^{b}**	**0.012**	**5.30^{b}**	**0.015**	**106.12^{a}**	**0.056**	**3.13^{a}**	**0.007**	**7.96^{a}**	**0.014**	**94.05**	**2.49^{A}**	**6.63^{A}**	**29.53**	**69.19**	**50.19**
100	**85.30**	**0.068**	**2.10^{a}**	**0.011**	**5.75^{a}**	**0.013**	**104.52^{a}**	**0.034**	**3.01^{a}**	**0.005**	**7.70^{b}**	**0.009**	**94.92**	**2.56^{A}**	**6.73^{A}**	**22.53**	**43.33**	**33.91**
Mean	**79.49**	**0.069**	**1.24^{B}**	**0.011**	**4.79^{B}**	**0.016**	**102.44**	**0.042**	**2.80^{A}**	**0.006**	**7.26^{A}**	**0.013**	**90.97**	**2.02**	**6.03**	**29.16**	**77.13**	**56.14**
Mean	**78.92**	**0.069**	**1.27**	**0.011**	**4.76**	**0.015**	**101.87**	**0.042**	**2.90**	**0.006**	**7.50**	**0.014**	**90.40**	**2.08**	**6.13**	**29.39**	**79.62**	**66.54**

Table (11) : Roots , shoots and seeds of snap bean plant content (concentration , % and uptake , mg / plant) of N , P and K and relative change (RC, %) of these nutrients concentration as affected by magnetized water under different levels of mineral N fertilization during first growing season (2011) .

Rate of added N Fertilizer (% of RD)	Non-magnetized water						Magnetized water						Relative change of nutrients concentration (RC , %)		
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		Nitrogen	Phosphorus	Potassium
	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)			
Roots															
0	**1.40 ^{d}**	**28.00**	**0.18 ^{d}**	**3.60**	**1.10 ^{d}**	**22.00**	**1.50 ^{d}**	**60.00**	**0.22 ^{d}**	**8.80**	**1.28 ^{d}**	**51.20**	**7.14**	**22.22**	**16.36**
50	**1.55 ^{c}**	**67.58**	**0.20 ^{c}**	**8.72**	**1.16 ^{c}**	**50.58**	**1.82 ^{c}**	**112.48**	**0.26 ^{c}**	**16.07**	**1.40 ^{c}**	**86.52**	**17.42**	**30.00**	**20.69**
75	**1.78 ^{b}**	**81.17**	**0.25 ^{b}**	**11.40**	**1.29 ^{b}**	**58.82**	**1.90 ^{b}**	**117.04**	**0.31 ^{b}**	**19.10**	**1.55 ^{b}**	**95.48**	**6.74**	**24.00**	**20.16**
100	**1.95 ^{a}**	**98.67**	**0.32 ^{a}**	**16.19**	**1.34 ^{a}**	**67.80**	**2.10 ^{a}**	**122.43**	**0.42 ^{a}**	**24.49**	**1.66 ^{a}**	**96.78**	**7.69**	**31.25**	**23.88**
Mean	**1.67 ^{B}**	**68.86**	**0.24 ^{B}**	**9.98**	**1.22 ^{B}**	**49.80**	**1.83 ^{A}**	**102.99**	**0.30 ^{A}**	**17.12**	**1.47 ^{A}**	**82.50**	**9.75**	**26.87**	**20.27**
Shoots															
0	**2.08 ^{d}**	**936.83**	**0.21 ^{b}**	**94.58**	**1.19 ^{d}**	**535.98**	**2.35 ^{d}**	**1935.93**	**0.25 ^{d}**	**205.95**	**1.48 ^{d}**	**1219.22**	**12.98**	**19.05**	**24.37**
50	**2.15 ^{c}**	**1296.88**	**0.24 ^{b}**	**144.77**	**1.25 ^{c}**	**754.00**	**2.52 ^{c}**	**2840.29**	**0.31 ^{c}**	**349.40**	**1.55 ^{c}**	**1747.01**	**17.21**	**29.17**	**24.00**
75	**2.28 ^{b}**	**1404.48**	**0.30 ^{a}**	**184.80**	**1.33 ^{b}**	**819.28**	**2.75 ^{b}**	**3051.40**	**0.39 ^{b}**	**432.74**	**1.68 ^{b}**	**1864.13**	**20.61**	**30.00**	**26.32**
100	**2.45 ^{a}**	**1627.54**	**0.38 ^{a}**	**252.43**	**1.40 ^{a}**	**930.02**	**2.93 ^{a}**	**2950.51**	**0.48 ^{a}**	**483.36**	**1.82 ^{a}**	**1832.74**	**19.59**	**26.32**	**30.00**
Mean	**2.24 ^{B}**	**1316.43**	**0.28 ^{B}**	**169.15**	**1.29 ^{B}**	**759.82**	**2.64 ^{A}**	**2694.53**	**0.36 ^{A}**	**367.86**	**1.63 ^{A}**	**1665.78**	**17.60**	**26.14**	**26.17**
Seeds															
0	**2.95 ^{d}**	**594.43**	**0.35 ^{d}**	**70.53**	**1.90 ^{cd}**	**382.85**	**3.42 ^{d}**	**1032.16**	**0.42 ^{d}**	**126.76**	**2.30 ^{d}**	**694.14**	**15.93**	**20.00**	**21.05**
50	**3.20 ^{c}**	**746.24**	**0.42 ^{c}**	**97.94**	**2.10 ^{c}**	**489.72**	**3.60 ^{c}**	**1267.20**	**0.51 ^{c}**	**179.52**	**2.55 ^{c}**	**897.60**	**12.50**	**21.43**	**21.43**
75	**3.50 ^{b}**	**938.00**	**0.52 ^{b}**	**139.36**	**2.25 ^{b}**	**603.00**	**3.92 ^{b}**	**1503.32**	**0.65 ^{b}**	**249.28**	**2.80 ^{b}**	**1073.80**	**12.00**	**25.00**	**24.44**
100	**3.68 ^{a}**	**1010.16**	**0.65 ^{a}**	**178.43**	**2.30 ^{a}**	**631.35**	**4.10 ^{a}**	**1537.50**	**0.82 ^{a}**	**307.50**	**2.85 ^{a}**	**1068.75**	**11.41**	**26.15**	**23.91**
Mean	**3.33 ^{D}**	**822.21**	**0.49 ^{B}**	**121.57**	**2.14 ^{B}**	**526.73**	**3.76 ^{A}**	**1335.05**	**0.60 ^{A}**	**215.77**	**2.63 ^{A}**	**933.57**	**12.96**	**23.15**	**22.71**

Table (12) : Roots , shoots and seeds of snap bean plant content (concentration , % and uptake , mg / plant) of N , P and K and relative change (RC , %) of these nutrients concentration as affected by magnetized water under different levels of mineral N fertilization during second growing season

Rate of added N Fertilizer (% of RD)	Non-magnetized water						Magnetized water						Relative change of nutrients concentration (RC , %)		
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		Nitrogen	Phosphorus	Potassium
	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)	Conc. (%)	Uptake (mg / plant)			
Roots															
0	1.42 d	31.95	0.20 b	4.50	1.07 d	24.08	1.48 d	48.10	0.23 d	7.48	1.30 d	42.25	4.23	15.00	21.50
50	1.53 c	62.88	0.22 b	9.04	1.17 c	48.09	1.80 c	97.74	0.24 c	13.03	1.40 c	76.02	17.65	9.09	19.66
75	1.80 b	80.28	0.23 b	10.26	1.27 b	56.64	1.90 b	102.79	0.30 b	16.23	1.52 b	82.23	5.56	30.43	19.69
100	1.90 a	87.02	0.31 a	14.20	1.31 a	60.00	2.12 a	112.57	0.42 a	22.30	1.59 a	84.43	11.58	35.48	21.37
Mean	1.66 B	65.53	0.24 B	9.50	1.21 B	51.70	1.83 A	90.30	0.30 A	59.04	1.45 A	71.23	9.76	22.50	20.56
Shoots															
0	2.06 d	857.58	0.20 d	83.26	1.20 d	499.56	2.30 d	1816.08	0.26 d	205.30	1.50 c	1184.40	11.65	30.00	25.00
50	2.20 c	1251.80	0.25 c	142.25	1.24 c	705.56	2.50 c	2737.25	0.30 c	328.47	1.52 c	1664.25	13.64	20.00	22.58
75	2.26 b	1314.87	0.28 b	162.90	1.31 b	762.16	2.80 b	3011.12	0.40 b	430.16	1.66 b	1785.16	23.89	42.86	26.72
100	2.45 a	1501.85	0.36 a	220.68	1.42 a	870.46	2.90 a	3032.82	0.46 a	481.07	1.85 a	1934.73	18.37	27.78	30.28
Mean	2.24 B	1231.53	0.27 B	152.27	1.29 B	709.44	2.63 A	2649.32	0.36 A	361.25	1.63 A	1642.14	16.89	30.16	26.15
Seeds															
0	2.92 d	590.42	0.32 d	64.70	1.88 d	380.14	3.40 d	1028.50	0.40 d	121.00	2.28 d	689.70	16.44	25.00	21.28
50	3.23 c	746.13	0.45 c	103.95	2.10 c	485.10	3.65 c	1281.15	0.53 c	186.03	2.54 c	891.54	13.00	17.78	20.95
75	3.50 b	910.00	0.52 b	135.20	2.23 b	579.80	3.95 b	1520.75	0.63 b	242.55	2.83 ab	1089.55	12.86	21.15	26.91
100	3.68 a	1002.80	0.64 a	174.40	2.30 a	626.75	4.10 a	1531.35	0.85 a	317.48	2.85 a	1064.48	11.41	32.81	23.91
Mean	3.33 B	812.34	0.48 B	119.56	2.13 B	517.95	3.76 A	1340.44	0.60 A	216.77	2.63 A	933.82	13.43	24.19	23.26

Table (4) : Available content (mg kg^{-1}) of N , P and K and its vertical redistribution and their relative change (RC) as a percentage (%) of original soil value affected by magnetized water under different levels of mineral N fertilization (Mean value of the two growing seasons , 2011 and 2012) .

Rate of added N Fertilizer (% of RD)	Non-magnetized water										Magnetized water									
	0 – 15 (cm)		15 – 30 (cm)		30 – 60 (cm)		60 – 90 (cm)		Mean		0 – 15 (cm)		15 – 30 (cm)		30 – 60 (cm)		60 – 90 (cm)		Mean	
	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / kg	RC (%)	mg / k g	RC (%)
	Nitrogen (N)																			
0	51.10	-7.43	40.20	-6.88	26.70	-6.32	19.82	-1.64	34.46	-6.26	66.66	20.76	50.80	17.67	34.15	19.82	25.75	27.79	44.34	20.62
50	53.50	-3.08	42.80	-0.857	28.00	-1.75	20.15	0.00	36.11	-1.77	73.55	33.24	56.50	30.88	40.40	41.75	30.95	53.60	50.35	36.97
75	55.50	0.544	49.15	13.85	30.30	6.32	20.40	1.24	38.84	5.66	78.50	42.21	65.50	51.73	47.80	67.72	37.65	86.85	57.36	56.04
100	62.13	12.55	54.55	26.36	30.95	8.60	21.50	6.70	42.28	15.02	80.20	45.29	70.90	64.23	55.85	95.96	44.83	122.48	62.95	71.25
Mean	55.56	0.646	46.68	8.12	28.99	1.71	20.47	1.58	37.92	3.16	74.73	35.38	60.93	41.13	44.55	56.31	34.80	72.68	53.75	46.22
	Phosphorus (P)																			
0	6.95	-4.14	5.30	-3.64	4.02	-4.29	3.50	0.00	4.94	-3.33	9.25	27.59	7.30	32.73	5.90	40.48	5.25	50.00	6.93	35.62
50	6.83	-5.79	5.10	-7.27	3.95	-5.95	3.50	0.00	4.85	-5.09	8.90	22.76	7.10	29.09	5.50	30.95	5.05	44.29	6.64	29.94
75	6.50	-10.34	4.95	-10.00	3.90	-7.14	3.45	-1.43	4.70	-8.02	8.50	17.24	6.60	20.00	5.32	26.67	4.91	40.29	6.33	23.87
100	6.10	-15.86	4.80	-12.73	3.90	-7.14	3.45	-1.43	4.56	-10.76	8.26	13.93	6.42	16.73	5.20	23.81	4.85	38.57	6.18	20.94
Mean	6.60	-9.03	5.04	-8.41	3.94	-6.13	3.48	-0.715	4.76	-6.80	8.73	20.38	6.86	24.64	5.48	30.48	5.02	43.29	6.52	27.59
	Potassium (K)																			
0	110.45	-4.12	103.70	-1.71	90.50	2.72	81.80	1.36	96.61	-0.791	142.20	23.44	127.35	20.71	125.56	42.52	92.95	15.18	122.02	25.30
50	106.71	-7.37	102.25	-3.08	88.88	0.885	81.20	0.620	94.76	-2.69	135.15	17.32	123.25	16.82	120.80	37.12	92.25	14.31	117.86	21.03
75	101.50	-11.89	96.35	-8.67	86.65	-1.65	80.70	0.00	91.30	-6.24	127.10	10.33	115.75	9.72	100.35	13.90	90.90	12.64	108.53	11.45
100	94.94	-17.59	90.70	-14.03	85.30	-3.18	80.70	0.00	87.91	-9.72	118.15	2.56	110.50	4.74	97.92	11.15	89.50	10.90	104.02	6.82
Mean	103.40	-10.24	98.25	-6.87	87.83	-0.306	81.10	0.495	92.65	-4.86	130.65	13.41	119.21	13.00	111.16	26.17	91.40	13.26	113.11	16.15