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RESPONSE OF BLACK CUMIN (*Nigella sativa* L.) TO FERTILIZATION WITH CHICKEN MANURE, MINERAL N FERTILIZER AND VARYING K DOSES UNDER DIFFERENT SOIL MOISTURE CONTENTS

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ABSTRACT

A pot experiment was conducted under greenhouse conditions at the experimental farm, Faculty of Agriculture, Zagazig University, Egypt, during the 2008–2009 winter season to investigate the effect of different soil moisture contents, nitrogen sources *i.e.* chicken manure (ChM) and ammonium sulphate (AS) at rates of 0, 60 and 120 mg N kg^{-1} soil, as well as K fertilization (0, 40, 60 and 80 mg K kg^{-1} soil) and their combinations on the production and quality of black cumin plant (*Nigella sativa* L.) grown on a clay soil. All treatments and their interactions had significant effects on the seed yield and growth characters as well as oil content, protein content and macronutrients content and uptake. The highest values of seed protein yield, N, P and K-uptake were obtained due to the addition of 120 mg N kg^{-1} as ChM and 80 mg K kg^{-1} under moisture content of 60% of field capacity (FC). While, the maximum values of seed yield and oil yield were attained due to application of 120 mg N kg^{-1} as AS and 80 mg K kg^{-1} as well as 120 mg N kg^{-1} as AS and 60 mg K kg^{-1}, respectively under moisture content of 60% FC. The maximum values of 1000-seed weight and protein content were achieved under moisture content of 80% FC due to 120 mg N kg^{-1} as ChM and 60 mg K kg^{-1} for 1000-seed weight and 120 mg N kg^{-1} as ChM and 40 mg K kg^{-1} for protein content, respectively. While, the highest one for each of dry weight $plant^{-1}$ and straw yield resulted owing to application of 120 mg N kg^{-1} as ChM and 80 mg K kg^{-1} under moisture content of 80% of field capacity (FC) treatment.

Key words: *Nigella sativa*, nitrogen, potassium, moisture content, yield, seed quality.

INTRODUCTION

Nigella sativa L. is a plant of the Ranunculacae family that produces seeds commonly known as black cumin which considered as unconventional oilseed, contains proteins, carbohydrates, and fixed oil (84% fatty acids, including linolenic and oleic) and volatile oils, alkaloids, saponins, crude fibre, as well as minerals, such as calcium, iron, sodium and potassium (Gali-Muhtasib *et al.,* 2006). Black cumin is one of the most revered medicinal seeds in history. The popularity of the plant was highly enhanced by the ideological belief in it as a cure for multiple diseases. In fact, this plant has occupied special place for the wide range of medicinal value (Ramadan, 2006). The importance of black cumin is attributed to the bioactive compound of thymoquinone which is as high as 25% in the seed oil (Pagola *et al.,* 2004). In traditional medicine, the oil component of the seeds is used to treat various diseases. Different types of research indeed substantiate a wide biological activity of black cumin oil, the active principle being thymoquinone (Ragheb *et al.,* 2009). There is evidence that the oil fraction of black cumin seeds has anti-carcinogenic (Swamy and Tan, 2000), anti-inflammatory (Ragheb *et al.,* 2009) and anti-microbial effects (Landa *et al.,* 2009).

It is accepted that adequate use of chemical fertilizer improve yield and quality of aromatic plants. Nitrogen is used in crop cultivation to enable full exploitation of the genetic potential of the crop. It is the nutrient that has the largest effect on plant physiology and is probably the

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single most important limiting nutrient for crop growth (Oren *et al.,* 2001). However, agricultural soils are often deficient in N and hence, to ensure adequate N supply to crops and prevent nutrient deficiencies, increasingly large amounts of inorganic N are employed, which remain unassimilated and result instead, in toxicity for the plant and soil alike (Shah, 2004 ; Boraste *et al.*, 2009). It is very important to find alternative methods for supplying nutrients to the growing plant to confront the previous problems. Nowadays, various researchers consider the utilization of organic fertilizers as promising alternative nutrition (Ali and Hassan, 2014).

The effective role of water supply on the growth and production of several medicinal plants was observed by many investigators they found that providing the plants with suitable water amounts resulted in better growth and yield than those grown under drought conditions. Farooq *et al.* (2009) reported that reduced water uptake results in a decrease in tissue water contents and turgor. Therefore, under drought stress conditions, cell elongation in plants is inhibited by reduced turgor pressure. Likewise, drought stress also trims down the photo-assimilation and metabolites required for cell division as a consequence, impaired mitosis, cell elongation and expansion result in reduced plant height and growth. Similar trends were also reported by (Bannayan *et al.*, 2008).

The present investigation aimed at assessing the effect of organic manure and conventional N- fertilizer or potassium fertilization and their combinations on growth, yield, chemical composition and quality of black cumin plants under two moisture contents of 80 and 60% of field capacity.

MATERIALS AND METHODS

A pot experiment was conducted under greenhouse conditions at the experimental farm Faculty of Agriculture, Zagazig University, Egypt, during the 2008–2009 season to investigate the effect of different soil moisture contents, nitrogen sources and rates as well as K fertilization and their combinations on the production of black cumin plant (*Nigella sativa* L.) grown on a clay soil collected from El-Zagazig, El-Sharkia Governorate, Egypt.

A representative soil sample (0–30 cm) was taken before planting to determine physical and chemical properties. Physical and chemical properties of the investigated soil are shown in Table 1.

Closed-bottom plastic pots were filled with 5 kg of crushed air-dried soil. The pots were arranged in a randomized complete block design, each treatment was replicated three times. The design was a factorial randomized complete block, involving 3 factors; factor A: soil moisture content (80 and 60 % of field capacity), factor B: nitrogen source (inorganic *i.e.,* Ammonium sulphate [AS (206 g N kg^{-1}) and organic nitrogen *i.e.,* chicken manure (Ch.M) at three rates *i.e.*, 0, 60 and 120 mg N kg^{-1} soil] and Factor C: Potassium fertilizer rate (K was added as K_2SO_4, 400 g K kg^{-1} at four rates *i.e.,* 0, 40, 60 and 80 mg K kg^{-1} soil).The following treatments were conducted under soil moisture content levels (60 and 80% of FC "field capacity".

The applied quantity of the manure was mixed thoroughly with the soil one month before planting. The chemical composition of the (Ch.M) is shown in Table 2. All pots received P at 13 mg P kg^{-1} as ordinary super phosphate (OSP). Tap water was used for irrigation. The applied fertilizers were mixed thoroughly with the soil before seedling.

Seeds of black cumin Plant (*Nigella sativa* L.) were sown, on November 15, 2008 and the seedlings were thinned to 5 plants pot^{-1}. At the end of growing season, plants were harvested and yield and yield attributes (*i.e.*, dry weight, plant height, main and secondary branches number, seed and straw yields) and chemical properties (*i.e.*, nitrogen, phosphorus, potassium and oil contents) were recorded.

Methods of Analyses

Soil and fertilizer analyses

Top soil samples (0 – 30cm) were collected, air-dried, crushed and sieved through a 2 mm sieve and analyzed for soil EC, pH, and available N, P and K contents according to methods cited by Black *et al.* (1965).

Table 1. Some physical and chemical properties of the investigated soil

Property	Value	Property	Value
Particle size distribution (%)		**Soluble ions (mmolc L^{-1})**	
Clay	52.81	Na^+	14.7
Silt	13.0	K^+	0.17
Fine sand	27.1	Ca^{++}	5.40
Coarse sand	7.10	Mg^{++}	6.43
Textural class	Clay	Cl^-	7.92
EC (dSm^{-1}) in soil paste	2.67	HCO_3^-	3.08
pH [Soil suspension 1:2.5]	7.88	$SO_4^=$	15.7
Organic matter (g kg^{-1})	5.11		

Available macro and micronutrients (mg kg^{-1} soil)							
	N	P	K	Fe	Mn	Zn	Cu
	53.0	8.42	188	5.96	4.66	2.38	0.52
Critical levels of nutrients in soil (mg kg^{-1} soil) after Page *et al.* (1982)							
Limits	N	P	K	Fe	Mn	Zn	
Low	< 40.0	< 5.0	< 85.0	< 4.0	< 2.0	< 1.0	
Medium	40 -80	5 -10	85 - 170	4 - 6	2 - 5	1 - 2	
High	> 80.0	> 10.0	> 170	> 6.0	> 5.0	> 2.0	

Table 2. Some chemical composition of the chicken manure used

Characteristic	EC dSm^{-1}	pH	C/N ratio	Organic matter, g kg^{-1}	Total macronutrients (g kg^{-1})			Total micronutrients (mg kg^{-1})		
					N	P	K	Fe	Mn	Zn
Value	4.3	7.1	4.1	230	26.3	51.1	3.53	19.2	1.70	0.43

Plant analyses

Representative samples of black cumin seeds were air dried; oven dried at 70°C, ground and 0.5 g of each sample was acid digested using H_2SO_4 and $HClO_4$ mixture to determine N, P and K using the methods described by Ryan *et al.* (1996). Crude protein in black cumin seeds was calculated by multiplying total N-content by 6.25, Swetal *et al.* (2012) and Gharby *et al.* (2014). Oil content of black cumin seeds was extracted by using petroleum ether in a soxhelt system HT apparatus according to the methods of AOAC (1984).

RESULTS AND DISCUSSION

Effect of Treatments on Yield Attributes and Yield of Black Cumin

Yield attributes

Some yield attributes of the black cumin plants are shown in Tables 3 and 4. The nitrogen sources at different doses and potassium fertilization under different moisture content treatments significantly increased the dry weight $plant^{-1}$, plant height, 1000-seed weight, number-main branched and number-secondary branches. This may be due to the essential role of potassium

Table 3. Effect of nitrogen sources and rates as well as potassium rates on dry weight (g) plant^{-1}, plant height (cm) and 1000-seed weight (g) of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K, mg.kg^{-1} (C)														
		0	40	60	80	Mean	0	40	60	80	Mean	0	40	60	80	Mean
		Dry weight (g) plant^{-1}					Plant height (cm)					1000-seed weight (g)				
80	Non-N	8.16	9.06	9.77	9.22	9.05	31.10	30.70	32.20	31.70	31.43	1.90	1.84	2.08	2.18	2.00
	ChM 60	13.14	15.36	16.44	18.60	15.89	37.80	38.10	38.60	39.00	38.38	2.27	2.29	2.32	2.25	2.28
	ChM 120	18.75	18.03	19.04	20.11	18.98	38.20	38.00	38.70	38.70	38.40	2.16	2.26	2.38	2.32	2.28
	AS 60	16.66	17.01	16.99	18.00	17.17	35.90	36.80	37.20	37.10	36.75	2.15	2.26	2.24	2.24	2.22
	AS 120	19.45	20.01	19.66	19.98	19.78	38.30	38.40	38.70	38.90	38.58	2.29	2.26	2.32	2.31	2.30
	Mean	15.23	15.89	16.38	17.18	16.17	36.26	36.40	37.08	37.08	36.70	2.15	2.18	2.27	2.26	2.22
60	Non-N	8.66	8.98	9.16	9.09	8.97	32.20	31.70	31.80	31.30	31.75	2.04	2.18	2.21	2.16	2.15
	ChM 60	14.15	14.66	16.55	18.01	15.84	38.30	37.80	38.40	38.70	38.23	2.15	2.21	2.24	2.26	2.22
	ChM 120	17.02	17.66	18.05	19.04	17.94	39.20	39.40	39.20	37.80	38.90	2.19	2.23	2.33	2.29	2.26
	AS 60	15.82	16.13	16.45	17.18	16.40	38.40	37.30	38.40	37.90	38.00	2.12	2.19	2.31	2.36	2.25
	AS 120	18.03	19.07	19.00	18.91	18.75	37.50	37.50	38.10	38.30	37.85	2.20	2.27	2.27	2.25	2.25
	Mean	14.74	15.30	15.84	16.45	15.58	37.06	36.74	37.18	36.80	36.95	2.14	2.22	2.27	2.26	2.22
							Mean of N treatments									
Non-N		8.41	9.02	9.47	9.16	9.01	31.65	31.20	32.00	31.50	31.59	1.97	2.01	2.15	2.17	2.07
ChM 60		13.65	15.01	16.5	18.31	15.86	37.90	37.95	38.50	38.85	38.30	2.21	2.25	2.28	2.25	2.25
ChM 120		17.89	17.85	18.55	19.58	18.46	38.70	38.70	38.95	38.25	38.65	2.18	2.25	2.35	2.31	2.27
AS 60		16.24	16.57	16.72	19.59	16.78	37.15	37.05	37.80	37.50	37.38	2.14	2.23	2.28	2.30	2.23
AS 120		18.74	19.54	19.33	19.45	19.26	37.90	37.95	38.40	38.60	38.21	2.25	2.27	2.30	2.28	2.27
Grand Mean		14.98	15,60	16.11	16.81	15.88	36.66	36.57	37.13	36.94	36.83	2.15	2.20	2.27	2.26	2.22
LSD 0.05		A	0.04	AB	0.80		A	0.09	AB	0.20		A	0.06	AB	0.14	
		B	0.06	AC	0.07		B	0.14	AC	0.18		B	0.10	AC	0.12	
		C	0.05	BC	0.11		C	0.12	BC	0.28		C	0.09	BC	0.20	
		ABC	0.16				ABC	0.39				ABC	0.28			

FC: Field capacity; ChM: Chicken manure; AS: Ammonium sulfate

A= moisture content; B= N-sources and rates; C= K-rates

Table 4. Effect of nitrogen sources and rates as well as potassium rates on number of main and secondary branches of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K, mg.kg^{-1} (C)									
		0	40	60	80	Mean	0	40	60	80	Mean
		No.-main branches					No.-secondary branches				
80	Non-N	6.10	6.40	6.50	6.20	6.30	20.10	22.10	21.60	20.20	21.00
	ChM 60	7.20	7.50	7.40	7.30	7.35	22.70	25.30	27.30	28.20	25.88
	ChM 120	7.80	7.90	9.10	8.80	8.40	23.60	28.70	25.80	29.40	26.88
	AS 60	8.10	8.40	8.50	8.20	8.30	25.30	28.60	26.40	28.20	27.13
	AS 120	7.90	7.80	8.90	8.80	8.35	28.50	29.10	29.50	29.30	29.10
Mean		7.42	7.60	8.08	7.86	7.74	24.04	26.76	26.12	27.06	26.00
60	Non-N	7.00	6.70	6.60	6.70	6.75	21.40	22.50	21.60	23.40	22.23
	ChM 60	7.40	7.30	7.50	7.70	7.48	24.70	26.30	26.90	28.00	26.48
	ChM 120	8.10	8.50	8.70	8.30	8.40	25.40	26.90	28.10	29.40	27.45
	AS 60	8.20	8.60	6.10	8.70	7.90	27.20	27.30	28.60	28.20	27.83
	AS 120	8.40	8.80	8.90	9.30	8.85	29.10	29.40	30.40	29.00	29.48
Mean		7.82	7.98	7.56	8.14	7.88	25.56	26.48	27.12	27.60	26.69
Mean of N treatments											
Non-N		6.55	6.55	6.55	6.45	6.53	20.75	22.30	21.60	21.80	21.61
ChM 60		7.30	7.40	7.450	7.50	7.41	23.70	25.80	27.10	28.10	26.18
ChM 120		7.95	8.20	8.90	8.55	8.40	24.50	27.80	26.95	29.40	27.16
AS 60		8.15	8.50	7.30	8.45	8.10	26.25	27.95	27.50	28.20	27.48
AS 120		8.15	8.30	8.90	8.05	8.60	28.80	29.25	29.95	29.15	29.29
Grand Mean		7.62	7.79	7.82	8.00	7.80	24.80	26.62	26.62	27.33	26.34
LSD 0.05	A		0.02	AB	0.06		A	0.12	AB	0.26	
	B		0.04	AC	0.05		B	0.18	AC	0.23	
	C		0.03	BC	0.07		C	0.16	BC	0.36	
	ABC		0.10				ABC	0.51			

See footnote in Table 2.

on growth and establishment of black cumin plants in addition to its role as an activator in the enzymatic reaction during plant growth. Also, nitrogen is the most important growth limiting factor for crops. Shah (2008) reported that the application of basal N, especially at the rate of 352 mg N pot^{-1}, had the most favorable effect on all the black cumin growth parameters studied.

The highest dry weight per plant and 1000-seed weight were recorded in the plants treated with ChM120 mg N kg^{-1} + K80 mg K kg^{-1} and ChM120 mg N kg^{-1} + K60 mg K kg^{-1} which caused increases of about 146% and 25%, respectively with 80% of field capacity. Maximum plant height at harvest (39.40 cm) was recorded under application of ChM120 mg N kg^{-1} + K40 mg K kg^{-1} in presence of 60% moisture content of field capacity. The highest increase in number of main branches (32.9%) and number of secondary branches (42.1%) were recorded in plants treated with AS120 mg N kg^{-1} + K80 mg K kg^{-1} and AS120 mg N kg^{-1} + K60 mg K kg^{-1}, respectively under moisture content of 60% field capacity.

Straw and seed yields

The data in Table 5 reveal that the increase in levels of fertilizers increased straw and seed yields of black cumin significantly at all the moisture contents. Higher levels of nitrogen and potassium fertilization may be attributed to more efficient nutritional environment in the root zone as well as in the plant system. The biological role of nitrogen as an essential constituent of chlorophyll in harvesting solar energy, phosphorylated compounds in energy transformations, nucleic acids in the transfer of genetic information and the regulation of cellular metabolism and of protein as structural units and biological catalysts is well documented (Swetal *et al.*, 2012). The enhancement of seed yield plant^{-1} can be explained on the fact that under optimal N nutrition CO_2 assimilation is favorably upregulated. This result in an adequate supply of photo-assimilates to the developing meristems, which enhances and maintains their growth. Thus, more reproductive structures are produced per plant and area, as is the case with seeds. The capacity of these seeds to grow is substantially probably increased because more cells with greater enzyme capacity are produced (Lowlor, 2002). A descending order characterized the effects of N fertilization on straw and seed yield as follows; for straw yield: AS120 mg N kg^{-1} > ChM120 mg N kg^{-1} > ChM60 mg N kg^{-1} > AS60 mg N kg^{-1} under 80% of FC. The corresponding order under 60% FC. was: ChM120 mg N kg^{-1} > AS120 mg N kg^{-1} > ChM60 mg N kg^{-1} > AS60 mg N kg^{-1}. For seed yield, the descending order was: AS120 mg N kg^{-1} > AS60 mg N kg^{-1} > ChM120 mg N kg^{-1} > ChM60 mg N kg^{-1} under both 80% and 60% FC. As for the main effect of K fertilization on straw and seed yield; the order was: K80 mg K kg^{-1} > K60 mg K kg^{-1} > K40 mg K kg^{-1}. The main effect of moisture content, 80% of FC increased the black cumin straw yield by 17.03%, while decreased seed yield by 13.18% as compared to the application of 60% FC.

The maximum straw and seed yields (13.00 and 8.82 g plant^{-1}) were achieved by application of 120 mg N kg^{-1} as ChM and 80 mg K kg^{-1} under 80% of FC and 120 mg N kg^{-1} as AS and 80 mg K kg^{-1} under 60% of FC and the corresponding increments over the non-treatment plants were 162% and 115%, respectively.

Seed Quality

Seed oil content and oil yield

Results presented in Table 6 show that the seed oil content and seed oil yield of black cumin increased significantly owing to application of N and K fertilization under soil moisture content of 80 and 60% of FC. These results are in agreement with those obtained by Hassan and Ali (2013) and Ali and Hassan (2014). As for N fertilization, the main effect shows significant increase and followed the order: ChM120 mg N kg^{-1} > AS120 mg N kg^{-1} > ChM60 mg N kg^{-1} > AS60 mg N kg^{-1} > control for seed oil content and AS120 mg N kg^{-1} > ChM120 mg N kg^{-1} > AS60 mg N kg^{-1} > ChM60 mg N kg^{-1} > control for seed oil yield. A descending order characterized the main effects of K fertilization rate on seed oil content and seed oil yield is as follows: K60 mg K kg^{-1} > K40 mg

Table 5. Effect of nitrogen sources and rates as well as potassium rates on straw and seed yields (g) plant^{-1} of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K,mg.kg^{-1} (C)									
		0	40	60	80	Mean	0	40	60	80	Mean
		Straw yield (g plant^{-1})					Seed yield (g plant^{-1})				
80	Non-N	4.97	5.25	6.55	5.30	5.52	3.19	3.81	3.22	3.92	3.54
	ChM 60	8.03	10.14	11.10	12.43	10.43	5.11	5.22	5.34	6.17	5.46
	ChM 120	12.54	11.51	12.43	13.00	12.37	6.21	6.52	6.61	7.11	6.61
	AS 60	10.33	10.19	9.78	10.69	10.25	6.33	6.82	7.21	7.30	6.92
	AS 120	12.63	12.78	12.35	12.76	12.63	6.82	7.23	7.31	7.22	7.15
	Mean	9.70	9.97	10.44	10.84	10.24	5.53	5.92	5.94	6.35	5.93
60	Non-N	4.55	5.10	4.95	5.13	4.93	4.11	3.88	4.21	3.96	4.04
	ChM 60	7.92	8.25	10.44	11.20	9.45	6.23	6.41	6.11	6.81	6.39
	ChM 120	9.91	10.14	10.39	11.05	10.37	7.11	7.52	7.66	7.99	7.57
	AS 60	8.40	8.45	9.07	9.27	8.80	7.42	7.68	7.38	7.91	7.60
	AS 120	9.82	10.59	10.32	10.09	10.21	8.21	8.48	8.68	8.82	8.55
	Mean	8.12	8.51	9.03	9.35	8.75	6.62	6.79	6.80	7.10	6.83
		Mean of N treatments									
Non-N		4.76	5.18	5.75	5.22	5.23	3.65	3.85	3.72	3.94	3.79
ChM 60		7.98	9.20	10.77	11.82	9.34	5.67	5.82	5.73	6.49	5.93
ChM 120		11.23	10.83	11.41	12.03	11.37	6.66	7.02	7.14	7.55	7.09
AS 60		9.37	9.32	9.43	9.98	9.52	6.88	7.25	7.30	7.61	7.26
AS 120		11.23	11.69	11.34	11.43	11.42	7.52	7.86	8.00	8.20	7.85
Grand Mean		8.91	9.24	9.74	10.09	9.50	6.07	6.36	6.37	6.72	6.38
LSD 0.05		A	0.12	AB	0.27		A	0.11	AB	0.24	
		B	0.19	AC	0.24		B	0.17	AC	0.22	
		C	0.17	BC	0.38		C	0.15	BC	0.34	
		ABC	0.53				ABC	0.48			

Table 6. Effect of nitrogen sources and rates as well as potassium rates on oil content (g kg^{-1}) and oil yield (g plant^{-1}) of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K, mg.kg^{-1} (C)									
		0	40	60	80	Mean	0	40	60	80	Mean
		Oil content (g kg^{-1})					Oil yield (g plant^{-1})				
80	Non-N	220.2	232.2	234.7	233.2	230.1	0.70	0.89	0.76	0.91	0.81
	ChM 60	280.7	281.7	279.6	258.8	275.2	1.43	1.47	1.49	1.60	1.50
	ChM 120	280.3	289.9	268.8	269.8	277.2	1.81	1.89	1.78	1.92	1.85
	AS 60	269.8	277.3	269.8	279.8	274.2	1.72	1.89	1.95	2.05	1.90
	AS 120	274.5	279.8	278.0	264.5	274.2	1.87	2.02	2.03	1.91	1.96
	Mean	265.1	272.2	266.2	261.2	266.2	1.50	1.63	1.60	1.68	1.60
60	Non-N	213.1	255.5	265.7	258.4	248.2	0.88	0.99	1.12	1.02	1.00
	ChM 60	241.6	268.9	283.5	263.9	264.5	1.51	1.72	1.73	1.80	1.69
	ChM 120	246.8	277.2	281.3	273.9	289.8	1.75	2.08	2.16	2.19	2.05
	AS 60	221.6	269.0	279.8	272.0	260.6	1.64	2.07	2.07	2.15	1.98
	AS 120	245.5	268.3	283.5	273.9	267.8	2.02	2.28	2.46	2.42	2.29
	Mean	233.7	267.8	278.8	268.4	262.2	1.56	1.83	1.91	1.92	1.80
		Mean of N treatments									
Non-N		216.7	243.9	250.2	245.8	239.1	0.79	0.94	0.94	0.97	0.91
ChM 60		261.2	275.3	281.6	261.4	269.8	1.47	1.60	1.61	1.70	1.59
ChM 120		263.6	283.6	275.1	271.9	273.5	1.78	1.99	1.97	2.05	1.95
AS 60		245.7	273.2	274.8	27.5.9	267.4	1.68	1.98	2.01	2.10	1.94
AS 120		260.0	274.1	280.8	269.2	271.0	1.94	2.15	2.25	2.16	2.13
Grand Mean		249.4	270.0	272.5	264.8	264.2	1.53	1.73	1.75	1.80	1.70
LSD 0.05		A	1.1	AB	2.4		A	0.03	AB	0.07	
		B	1.7	AC	2.2		B	0.05	AC	0.09	
		C	1.5	BC	3.4		C	0.04	BC	0.10	
		ABC	4.8				ABC	0.14			

K kg^{-1} > K80 mg K kg^{-1} and K80 mg K kg^{-1} > K60 mg K kg^{-1} > K40 mg K kg^{-1}, respectively. The main effects of moisture content treatments on seed oil yield showed a descending increase in the order of 60% of FC > 80% FC. El-Mekawy (2012) found that seed oil content of black cumin was increased under drought condition after flowering.

Seed oil content of plants treated with 120 mg N kg^{-1} as Ch.M and 40 mg K kg^{-1} under the moisture 80% of FC was the highest and gave an increase of 31.8%. The highest value of seed oil yield (2.46 g $plant^{-1}$) was obtained under application of 120 mg N kg^{-1} as AS and 60 mg K kg^{-1} with 60% of FC causing 180% increase.

Seed protein content and protein yield

The responses of seed protein content and seed protein yield to various fertilizers applied in this experiment are shown in Figs. 1 and 2. The data illustrate that application of N and K fertilizers increased the protein content and protein yield of black cumin seeds. This was true for the two N sources used. This is expected, as N is vital in protein structure as well as being an active constituent of RNA and DNA, which are essential for protein synthesis (Marschner, 1995). An equally potent effect of N on protein content was found to arise through an enhancement of NR activity. NR is the regulatory enzyme in the N metabolism and is responsible for the reduction of nitrate to ammoniacal N, which is then incorporated in the production of amino acids and thereby optimizing their condensation into proteins (Hopkins, 1995). These results are in agreement with those obtained by Abbas *et al.* (2011) and Wortman *et al.* (2011). Increasing N rate was associated with increases seed protein content and seed protein yield; and ChM was superior to AS especially, with higher rate of 120 mg N kg^{-1} soil.

In the present study, seed protein content and seed protein yield increased by increasing K rate. However, there was a slight decrease in the seed protein content at K rates over 40 mg K kg^{-1} soil. Helmy and Ramadan (2013) reported that K application increased protein content of peanut seed by about 17% and 10% for the rates 60 and 120 mg K kg^{-1}, respectively. The average increases followed the order of 40 mg K kg^{-1} > 60 mg K kg^{-1} > 80 mg K kg^{-1} causing increases by about 4.45%, 4.06% and 2.45% for seed protein content and 80 mg K kg^{-1} > 60 mg K kg^{-1} = 40 mg K kg^{-1} causing 13.8%, 9.57% and 9.57% increases for seed protein yield.

Regarding the effect of moisture treatments, data show that 60% moisture content of FC gave greater seed protein content and seed protein yield as compared with 80% FC with an increase of 4% and 18.4 %, respectively.

The maximum mean value of protein content (193.8 g kg^{-1}) and protein yield (1.493 g $plant^{-1}$) was observed by the combination of 120 mg N kg^{-1} as ChM and 40 mg K kg^{-1} under 80 % of FC and 120 mg N kg^{-1} as ChM and 80 mg K kg^{-1} under 60 % of FC, respectively.

Macronutrient content and uptake

An increment occurred in nitrogen, phosphorus and potassium contents and uptake in black cumin seeds when treated with N and K fertilizations or any combination treatment between them under the two moisture contents of 60% and 80% of FC.

Nitrogen content and uptake

Results given in Table 7 reflect significant increases in the N content and uptake as affected by application of the treatments for black cumin seed. The highest increase in nitrogen content 52.0% was recorded in the plants treated ChM120 + K40 + 80% FC. This may be due to that organic manure is a product which contains many elements and improves soil fertility as well as increases availability of nutrients and, consequently increases plant growth, yield and chemical composition (El-Sharkawy and Abdel-Razzak, 2010). The obtained results support other results obtained by Jhaa *et al.* (2011); Raissi *et al.* (2012); Swetal *et al.* (2012) and Hassan and Ali (2013). The main effects of moisture content, N-fertilization and K-doses on seed-N content show the following order: 60% > 80%; ChM120 mg N kg^{-1} > AS120 mg N kg^{-1} > AS60 mg N kg^{-1} > ChM60 mg N kg^{-1} and K80 mg K kg^{-1} > K60 mg K kg^{-1} > K40 mg K kg^{-1}, respectively.

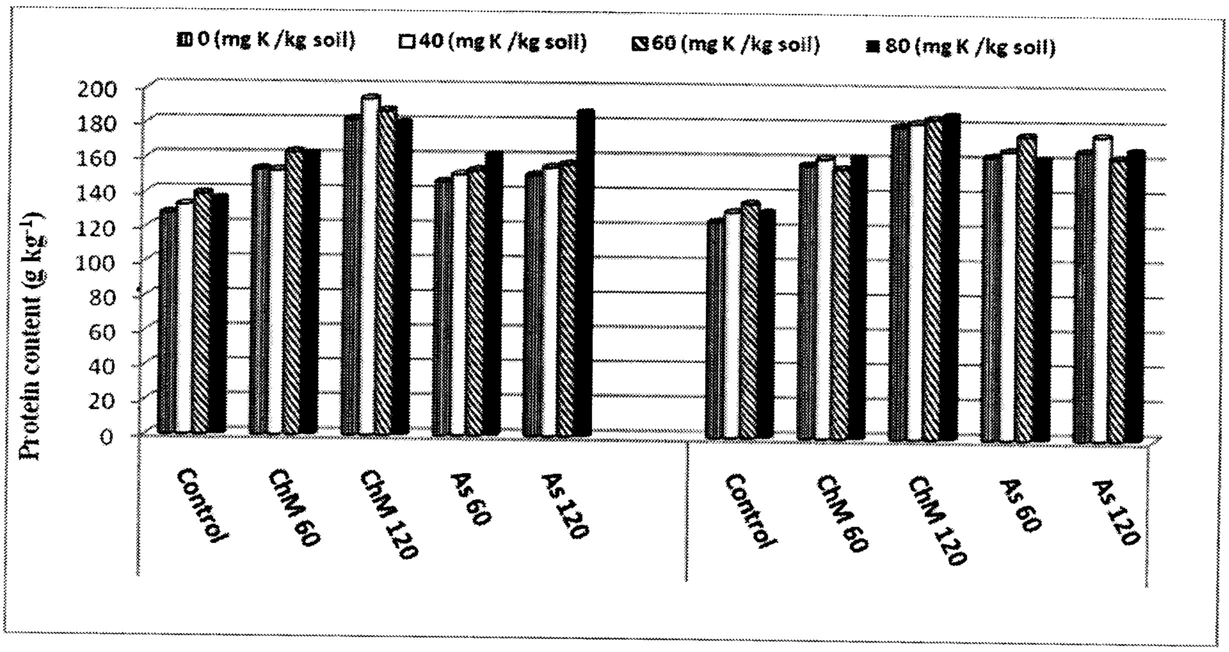

Fig. 1. Protein content (g kg^{-1}) of black cumin seeds as affected by nitrogen sources, rates and potassium rates under different moisture contents

FC: Field capacity; ChM: Chicken manure; AS: Ammonium sulphate at 60 and 120 mg N kg^{-1} soil

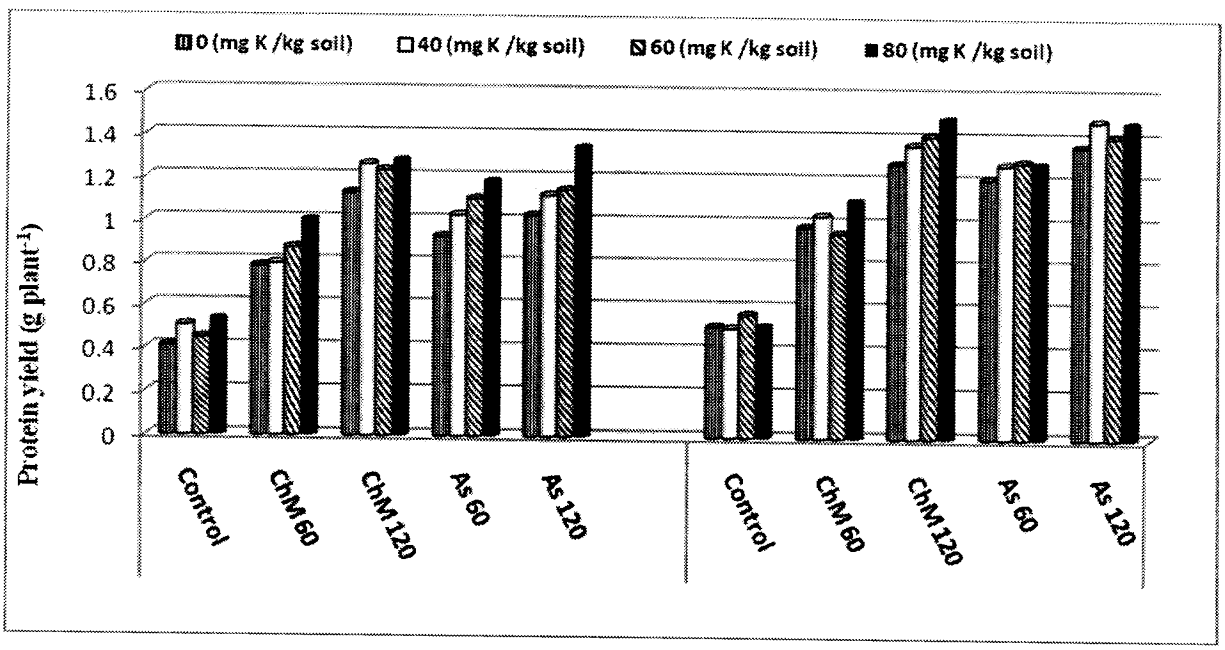

Fig. 2. Protein yield (g plant^{-1}) of black cumin seeds as affected by nitrogen sources, rates and potassium rates under different moisture contents

FC: Field capacity; ChM: Chicken manure; AS: Ammonium sulphate at 60 and 120 mg N kg^{-1} soil.

Table 7. Effect of nitrogen sources and rates as well as potassium rates on seed-N content (g kg^{-1}) and N-uptake, mg $plant^{-1}$ of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K, $mg.kg^{-1}$ (C)									
		0	40	60	80	Mean	0	40	60	80	Mean
		N-content					N-uptake				
80	Non-N	20.4	21.2	22.2	21.8	21.0	65.1	80.8	71.5	85.5	75.7
	ChM 60	24.5	24.4	26.1	26.0	25.3	125.2	127.4	139.4	160.4	138.1
	ChM 120	29.1	31.0	29.9	28.9	29.7	180.7	202.1	197.6	205.5	196.5
	AS 60	23.4	24.1	24.5	26.0	24.5	148.1	164.4	176.7	189.8	169.7
	AS 120	24.1	24.8	25.1	29.9	26.0	164.4	179.3	183.5	215.9	185.8
Mean		24.3	25.1	25.6	26.5	25.4	136.7	150.8	153.7	171.4	153.2
60	Non-N	19.9	20.8	21.6	20.9	20.8	81.8	80.7	90.9	82.8	84.1
	ChM 60	25.2	25.8	24.9	26.0	25.5	157.0	165.4	152.1	177.1	162.9
	ChM 120	28.8	29.1	29.5	29.9	29.3	204.8	218.8	226.0	238.9	222.1
	AS 60	26.1	26.6	28.0	26.0	26.7	193.7	204.3	206.6	205.7	202.6
	AS 120	26.6	28.0	26.0	26.8	26.9	218.4	237.4	225.9	236.4	229.5
Mean		25.3	26.1	26.0	25.9	25.8	171.1	181.3	180.3	188.2	180.2
Mean of N treatments											
Non-N		20.2	22.6	21.9	17.4	20.9	73.4	86.8	81.2	68.4	79.9
ChM 60		24.9	25.1	25.5	26.0	25.4	141.1	146.4	145.8	168.7	150.5
ChM 120		29.0	30.1	29.7	29.4	29.5	192.7	210.5	211.8	222.2	209.3
AS 60		24.8	25.4	26.3	26.0	25.6	170.9	184.3	191.6	197.7	186.2
AS 120		25.4	26.4	25.6	28.4	26.4	191.4	208.4	204.6	226.1	207.6
Grand Mean		24.8	25.6	25.8	26.2	25.6	153.9	166.1	167.0	179.8	166.7
LSD 0.05		A	0.52	AB	1.13		A	0.51	AB	1.14	
		B	0.81	AC	1.02		B	0.73	AC	1.02	
		C	0.71	BC	1.64		C	0.72	BC	1.61	
		ABC	2.21				ABC	2.27			

Highest seed-N uptake (238.9 mg plant^{-1}) was recorded in the plants treated with ChM120 mg N kg^{-1} + K80 mg K kg^{-1} under moisture content 60% of FC representing an increase of 192%.

Phosphorus content and uptake

Phosphorus content and uptake in black cumin seed increased significantly as a result of N-application, K-fertilization and moisture content (Table 8) singly or in combinations. The positive effect of organic manure reflects the different characteristics of the added chicken manure (chemical composition and nutritional status). The organic manures would create favorable soil physical and chemical conditions, which favorably affect the solubility and availability of nutrients and thus increase the uptake of nutrient. The released N is essential for plant growth and development involved in vital plant functions such as photosynthesis, DNA synthesis, protein formation and respiration (Diacono *et al.*, 2013). These results coincide with the results of Abbas *et al.* (2011) and Namvar and Khandan (2013).

The main effects of N, K fertilization and moisture content treatments shows a descending increase for P uptake in seeds in the order: ChM120 mg N kg^{-1} > AS120 mg N kg^{-1} > AS60 mg N kg^{-1} > ChM60 mg N kg^{-1}; K80 mg K kg^{-1} > K40 mg K kg^{-1} > K60 mg K kg^{-1} and 60% FC > 80% FC, respectively.

The highest P content of 18.4 g kg^{-1} in seeds was observed due to AS 60 + K40 under 60% FC while, for P-uptake 143.8 mg plant^{-1} was achieved due to 120 mg N kg^{-1} as Ch.M and 80 mg K kg^{-1} treatment under moisture content 60% of FC.

Potassium content and uptake

As shown in Table 9, K content and uptake in seeds followed a rather similar trend as that of N and increased significantly owing to application of N, K application and moisture content. As for the effect of N application, the main effect shows ChM120 > AS120 > AS60 > ChM60. The main effect of K-fertilization shows: K80 > K60 > K40. The data also show that moisture (%) application of 60% of FC increased seed K-uptake by 14.9% over the application of 80% of FC.

Shah (2007) reported that nutrient (NPK) uptake of *Nigella sativa* L. was favourably influenced by the application of inorganic N and increased with increasing N dosage, being maximum at 352 mg N pot^{-1}.

The maximum values of K content and uptake by black cumin (17.9 g kg^{-1} and 141.4 mg plant^{-1}, respectively) were obtained due 120 mg N kg^{-1} as Ch.M and 80 mg K kg^{-1} treatment under moisture content of 80% FC for K-content and 60% FC for K-uptake. Increases were 77.2% and 184.5%, respectively over the non-treated.

Conclusion

This study illustrates that applying chicken manure increased nitrogen, phosphate and potassium availability in black cumin plants and consequently promoted the vegetative growth and increased seed yield. Such treatments would reduce the production cost by minimizing or eliminating the use of chemical fertilizers, as well as decrease environmental hazards and improve soil structure, and obtain high quality black cumin seeds and oil. The treatment of chicken manure at 120 mg N kg^{-1} combined with 80 mg K kg^{-1} would thus be recommended.

Table 8. Effect of nitrogen sources and rates as well as potassium rates on seed-P content (g kg^{-1}) and P-uptake, mg plant^{-1} of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K, mg.kg^{-1} (C)									
		0	40	60	80	Mean	0	40	60	80	Mean
		P-content					P-uptake				
80	Non-N	12.2	12.4	12.3	12.8	12.4	38.9	47.2	39.6	50.2	44.0
	ChM 60	15.2	15.3	16.0	17.1	15.9	77.7	79.9	85.4	105.5	87.1
	ChM 120	17.6	18.2	17.7	17.9	18.1	109.3	118.7	117.0	127.3	118.1
	AS 60	14.2	14.8	13.9	14.0	14.2	89.9	100.9	100.2	102.2	98.3
	AS 120	15.0	14.8	14.3	15.1	14.8	102.3	107.0	104.5	109.0	105.7
	Mean	15.0	15.1	14.8	15.4	15.1	84.9	90.7	89.4	99.0	90.6
60	Non-N	12.6	12.4	12.3	12.8	12.5	51.8	48.1	51.8	50.7	50.6
	ChM 60	14.9	15.8	15.3	16.2	15.6	92.8	101.3	93.5	110.3	99.5
	ChM 120	17.9	18.1	18.2	18.0	18.0	127.3	136.1	139.4	143.8	136.7
	AS 60	15.0	18.4	18.0	17.2	17.2	111.3	141.3	132.8	136.1	130.4
	AS 120	15.1	14.8	14.6	15.0	14.9	124.0	125.5	126.7	132.3	127.1
	Mean	15.1	15.9	15.7	15.8	15.6	101.4	110.5	108.9	114.6	108.8
Mean of N treatments											
Non-N		12.4	12.4	12.3	12.8	12.5	45.4	47.7	45.7	50.4	47.3
ChM 60		15.1	15.6	15.7	16.7	15.7	85.3	90.6	89.5	107.9	93.3
ChM 120		17.8	18.2	18.0	18.0	18.0	118.3	127.4	128.2	135.6	127.4
AS 60		14.6	16.6	16.0	15.6	15.7	100.6	121.1	116.5	119.1	114.3
AS 120		15.1	14.8	14.5	15.1	14.8	113.1	116.3	115.6	120.7	116.4
Grand Mean		15.1	15.5	15.3	15.6	15.4	92.5	100.6	99.1	106.7	99.7
LSD 0.05		A	0.12	AB	0.23		A	0.18	AB	0.39	
		B	0.13	AC	0.22		B	0.28	AC	0.35	
		C	0.11	BC	0.33		C	0.25	BC	0.55	
		ABC	0.41				ABC	0.78			

Table 9. Effect of nitrogen sources and rates as well as potassium rates on seed-K content (g kg^{-1}) and K-uptake, mg $plant^{-1}$ of black cumin plant under different moisture contents

Moisture contents FC (%) (A)	N-Source and rates mg N kg^{-1} (B)	Rate of K, $mg.kg^{-1}$									
		0	40	60	80	Mean	0	40	60	80	Mean
		K-content					K-uptake				
80	Non-N	10.1	12.2	13.0	13.0	12.2	32.2	46.5	41.9	51.0	42.9
	ChM 60	16.1	17.1	15.2	16.2	16.2	82.3	89.3	81.2	100.0	88.2
	ChM 120	17.1	17.2	17.2	17.9	17.4	106.2	112.1	113.7	127.3	114.8
	AS 60	12.8	14.5	15.1	15.0	14.4	81.0	98.9	108.9	109.5	99.6
	AS 120	12.1	13.5	14.0	14.2	13.5	82.5	97.6	102.3	102.5	96.3
	Mean	13.6	14.9	14.9	15.3	14.7	76.9	88.9	89.6	98.0	88.3
60	Non-N	12.1	11.8	12.2	13.5	12.4	49.7	45.8	51.4	53.5	50.1
	ChM 60	16.6	16.8	16.2	17.1	16.7	103.4	107.7	99.0	116.5	106.6
	ChM 120	17.2	17.2	17.1	17.7	17.3	122.3	129.3	131.0	141.4	131.0
	AS 60	13.0	13.3	15.0	14.8	14.0	96.5	102.1	110.7	117.1	106.6
	AS 120	13.0	12.8	13.3	13.8	13.2	106.7	108.5	115.4	121.7	113.1
	Mean	14.4	14.4	14.8	15.4	14.7	95.7	98.7	101.5	110.0	101.5
					Mean of N treatments						
Non-N		11.1	12.0	12.6	13.3	12.2	41.0	46.1	46.6	52.2	46.5
ChM 60		16.4	17.0	15.7	16.7	16.4	92.8	98.5	90.1	108.2	97.4
ChM 120		17.2	17.2	17.2	17.8	17.3	114.2	120.7	122.3	134.4	122.9
AS 60		12.9	13.9	15.1	14.9	14.2	88.7	100.5	109.8	113.3	103.1
AS 120		12.6	13.2	13.7	14.0	13.3	94.6	103.1	108.9	112.1	104.7
Grand Mean		14.0	14.6	14.8	15.3	14.7	86.3	93.8	95.5	104.0	94.9
LSD 0.05		A	0.42	AB	0.91		A	0.31	AB	0.70	
		B	0.61	AC	0.82		B	0.49	AC	0.62	
		C	0.63	BC	1.24		C	0.44	BC	0.99	
		ABC	1.71				ABC	1.39			

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استجابة حبة البركة للتسميد بمخلفات الدواجن، السماد النيتروجيني المعدني ومعدلات مختلفة من البوتاسيوم تحت مستويات رطوبة تربة مختلفة

منى مجدي محمد - أيمن محمود حلمي - عادل عبد الرحمن شيحة- محمود نبيل إبراهيم خليل

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أقيمت تجربة أصص تحت ظروف الصوبة المحمية بمزرعة التجارب بكلية الزراعة - جامعة الزقازيق - مصر خلال موسم شتاء ٢٠٠٨/٢٠٠٩ وذلك لدراسة مدي استجابة نبات حبة البركة للتسميد النيتروجيني من مصادر مختلفة (عضوي من مخلفات الدواجن و معدني من سلفات الأمونيوم) وذلك بمعدلات مختلفة ٠ ، ٦٠ و ١٢٠ ملجم نيتروجين كجم$^{-1}$ تربة في وجود معدلات من التسميد البوتاسي ٠ ، ٤٠ ، ٦٠ و ٨٠ ملجم بوتاسيوم كجم$^{-1}$ تربة وتداخلاتهم على إنتاجية وجودة حبة البركة النامية في أرض طينية تحت تأثير مستويين من المحتوي الرطوبي للتربة، أدت جميع المعاملات المستخدمة وتداخلاتها إلي تأثير معنوي علي محصول الحبوب، الصفات المحصولية ، محتوي الزيت ، محتوي البروتين وكذلك محتوي بعض العناصر الكبرى (النيتروجين، الفوسفور والبوتاسيوم) والكمية الممتصة منها، أعلى قيم لمحصول البروتين للحبوب و الكميات المممتصة من عناصر النيتروجين، الفوسفور والبوتاسيوم قد تم التحصل عليها باستخدام معاملة الإضافة (١٢٠ملجم نيتروجين كجم$^{-1}$ على صورة مخلفات الدواجن + ٨٠ ملجم بوتاسيوم كجم$^{-1}$) وذلك تحت مستوي رطوبة ٦٠% من السعة الحقلية للتربة بينما كانت أقصي قيم لمحصول الحبوب و الزيت بها قد توصل إليها نتيجة معاملة الإضافة (١٢٠ ملجم نيتروجين كجم$^{-1}$ من سلفات الأمونيوم + ٨٠ ملجم بوتاسيوم كجم$^{-1}$ و ١٢٠ ملجم نيتروجين كجم$^{-1}$ من سلفات الأمونيوم +٦٠ ملجم بوتاسيوم كجم$^{-1}$) على التوالي و ذلك تحت مستوي رطوبة ٦٠% من السعة الحقلية للتربة، أعلى قيم لوزن الألف حبة و ومحتوي الحبوب للبروتين قد تحققت تحت مستوي رطوبة ٨٠% من السعة الحقلية للتربة نتيجة لمعاملة الإضافة (١٢٠ملجم نيتروجين كجم$^{-1}$ على صورة مخلفات الدواجن + ٦٠ ملجم بوتاسيوم كجم$^{-1}$) لوزن الألف حبة و(١٢٠ ملجم نيتروجين كجم$^{-1}$ على صورة مخلفات الدواجن + ٤٠ ملجم بوتاسيوم كجم$^{-1}$) لمحتوي الحبوب من البروتين على التوالي بينما كانت أعلى قيم للوزن الجاف نبات$^{-1}$ ومحصول القش نتجت بسبب استخدام (١٢٠ ملجم نيتروجين كجم$^{-1}$ على صورة مخلفات الدواجن + ٨٠ ملجم بوتاسيوم كجم$^{-1}$) وذلك تحت مستوي رطوبة ٨٠% من السعة الحقلية للتربة).

المحكمـــــون:

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