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Response of Growth and Yield of Eggplants (*Solanum melongena* L.) to Organic Mulches and Nitrogen Fertilization Levels During Late Summer Season

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TWO FIELD experiments were conducted with eggplant (cv. Sawad El laiel F_1, supplied by Samtrade company) during the successive summer seasons of 2013 and 2014 at a private farm, Kafr El-sheikh Governorate, Egypt to investigate the effect of nitrogen rates (50, 100 and 150kg/fed.), organic mulch (Rice straw, wheat straw and dry grass as well as the bare soil as a control), and their interaction on vegetative growth parameters, yield and fruit quality of eggplants. The obtained results showed that increasing N applied rate was accompanied with significant increases in vegetative growth characterstics (plant height (cm), number of branches and leaves, leaf area (cm^2), plant fresh weight (g), both early and total yield and fruit quality (average fruit weight (g) and both length and width of fruit (cm) by increasing N rates up to 150 kg/fed. On the other hand, nitrogen use efficiency was decreased with increment of N rate. Organic mulch treatments had a positive effect on vegetative growth parameters, total yield, fruit quality and nitrogen use efficiency compared with bare soil which had the highest early yield. The best results of aforementioned parameters were recorded by using different types of organic mulch and plants fertilized with 100 kg/fed of Nitrogen.

Keywords: Eggplant, Nitrogen rate, Organic mulch, Nitrogen use efficiency.

Eggplant (*Solanum Melongena*, L.) is one of the most important and popular vegetable crops in Egypt and is considered as a national diet in many other tropical and sub – tropical countries. Eggplant fruits contain a considerable amount of carbohydrates, proteins and some minerals (El-Nemr *et al*., 2012).

Plant nutrition is one of the most important factors that increase plant production, nitrogen is one of the major elements for plant growth and development that has an important role in plant nutrition and therefore is the yield – limiting factor for plant growth in many areas especially in low organic soil (Najafva Direkvandi *et al*., 2008). Many investigators reported that maximum yield of eggplant can be achieved with the application of N fertilizer at rate ranging from 20-80 kg/ha. (Moraditochaee *et al.,* 2011, Bozorgi, 2012 and

Azarpour *et al*., 2012). Aminifard *et al. (*2010) showed that the best yield of eggplant was resulted with 100 kg N per hectar. Also, many studies indicated that growth and yield of eggplant gradually increased with increasing the levels of nitrogen until 120 kg/ha.(Feleafel, 2005, Amiri *et al*., 2012 and Aman & Rab, 2013) and until 150 kg/ha. with (Lima *et al*., 2014).

Kostadinov and Kostadinova (2014) reported that the yield of eggplant was significantly increased with increasing rates of N to 240 kg/ha. Also, they added that the agronomic efficiency of nitrogen was strongly and positively related to the physiological and recovery efficiency as well as to the nitrogen harvest index. Feleafel and Mirdad (2013) achieved the highest yield of eggplant by using the nitrogen rate 250 kg/ha. Halitligil *et al.* (2002) studied three different N levels, 200,400 and 600 kg/ha. in drip irrigation for 50,100 and 150 mg N/L. treatments, and they found that the highest yield of eggplant was achieved with treatment of 150 mg N/L. (400 kg N/ha.). Also, they concluded that the nitrogen use efficiency (NUE) was significantly increased by applying the nitrogen fertilizer rate.

Surface mulch either by synthetic plastic films or natural organic waste material is recently being used to protect plants from root borne diseases and for water conservation. organic mulches including sawdust, dry grass, lawn clippings, maize cobs, rice and wheat straw, water hyacinth etc., have been very effective for vegetative growth and yield through improving soil water content. soil temperature and adding some of the organic nitrogen and other minerals to improve soil nutrient status. Increase plant growth and yield, moderation of soil temperature, conservation of water, reduction of nutrient loss by leaching and control of weeds are some advantages of mulching in growing eggplant or other commercial vegetable crop (Pessarakli and Dris, 2004).

Many investigators indicated that, organic mulch has a favorable effect on growth, yield and quality of vegetable crops (Carter & Johnson, 1988, El- Sawy, 1993, Abdul–Baki and Stommel, 1996, El-Aidy *et al.*, 2000, Thakur *et al.*, 2000, Thakur *et al.*, 2002, Rodriguez, 2007, Saeed & Ahmad, 2009, Sathappan *et al.*, 2012 and Pirbonch *et al.*, 2012).

Shaikh and Fouda (2008) reported that the maximum soil temperature about 3^0C with using wheat straw mulch and the yield of cucumber plants was increased by 67% compared with the plants growing with bare soil. Law *et al. (*2006) cleared that application organic mulches, straw, compost and wood chips, significantly increased the pepper yield compared with the bare soil.

Thus, the objective of the present work was to study the effect of nitrogen rates and organic mulches on growth, yield and the fruit quality of eggplant.

Materials and Methods

This study was carried out at a private farm in El-Shamarka village, Kafrelsheikh Governorate, Egypt during the late summer seasons of 2013 and 2014. The experiments were conducted on eggplant, cv. Sawad El-Laiel F_1 hybrid (*supplied by Samtrade company*).

The soil texture was clay, physical and chemical analysis were determined according to Jackson & Strelec (1967) and Black (1965), the data presented in Table 1.

TABLE 1. Physical and chemical analysis of soil before conducting the experiment during 2013 and 2014 seasons.

Soil properties	Seasons	
	2013	**2014**
Sand %	21.45	22.47
Silt %	29.60	30.17
Clay %	48.95	47.36
Soil type	clay	clay
pH	8.57	8.41
Ec/ 25^0C (mmhos/ cm)	3.7	3.4
Available N (mg/100g soil)	32.70	40.53
Available P (mg/100g soil)	10.71	9.02
Available K (mg/100g soil)	104.06	103.50

The seedlings of eggplant were transplanted on 10^{th} and 7^{th} of May in the first and second seasons, respectively, on both sides of each ridge (1.6 m width and 6 m long) at a space of 0.5 m between plants. Each plot consisted of two ridges having an area of 19.2 m^2, a guard row was left between each two adjacent plots. Fertilization of the experiments were 300 kg/fed. Calcium super phosphate (15% p_2o_5) 200 kg/fed was added during soil preparation. Potassium sulphate (50% K_2o) were divided into three equal parts added with the first irrigation, one month after transplanting and two months later. Furrow irrigation system was used and the control of weeds, insects and diseases was carried out when it was necessary.

Treatments used and experimental design, Nitrogen rates, i.e., 50, 100 and 150 kg/fed. were used as ammonium nitrate, divided into three equal parts added with first irrigation, with the first flowering and after the second picking date. The mulch treatments were rice straw, wheat straw, dry grass and bare soil as control. The organic mulches were spread on the soil (about 85% from soil surface was covered) between the rows and around plants after 5 days from transplanting, the thickness of organic mulches layer was about 5 cm. A Split–plot design with three replicates was used. The N rates were randomly arranged in the main plots while, the mulch treatments were randomly distributed in the sub- plots.

In each experimental unit the first ridge was allocated to measuring the vegetative growth characters, at 110 days after transplanting, *i.e.* plant height (cm), number of branches, number of leaves, leaf area (cm^2) and plant fresh weight (g), the second one was regard to determine the yield and its components, i.e, the early yield (fruits weight of the first four pickings in plot and converted into ton/fed.), the total yield (total fruits weight of all pickings / season (15 pickings) for plot and converted into ton/fed.) and nitrogen use efficiency (NUE) according to the equation of: NUE = Total fruits yield (ton / fed.) / N application rate(kg/fed) of each treatment. Harvesting started at about 45 days after transplanting and continued until the end of experiments in October in both seasons.

Five fruit from each sub- plot were taken randomly to determine the fruit characteristics, average fruit weight (g), fruit length and fruit width (cm). Soil temperature was recorded at 5 cm depth under the soil surface at 3- day intervals during the growing season and recorded twice daily at 7 a.m. (minimum) and 14 p.m. (maximum) by using the thermometers. Average soil temperatures for mulching treatments were calculated as monthly average (Table 2). Data were tested by analysis of variance according to Little and Hills (1972). Duncan's multiple range test was used for comparison among treatments means.

TABLE 2. Maximum and minimum monthly soil temperature (°C) as affected by organic mulch during the two growing seasons of 2013 and 2014.

Month	2013 Season							
	Bare soil		Rice straw		Wheat straw		Dry grass	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
June	31.5	24.7	27.5	26.0	28.3	26.4	28.1	26.4
July	30.5	25.7	27.2	26.4	27.2	26.3	27.4	27.7
August	32.2	25.6	28.2	26.2	28.9	26.6	26.5	28.7
September	29.3	24.3	26.3	25.1	26.5	25.4	26.4	25.4
2014 Season								
June	35.9	23.0	30.5	27.9	31.4	28.4	31.6	28.7
July	34.1	26.9	30.0	28.0	31.3	28.4	31.1	27.9
August	33.2	25.2	31.0	29.0	30.5	28.6	30.3	28.4
September	30.5	23.8	27.7	25.3	27.3	25.2	27.8	22.3

Results and Discussion

Vegetative Growth

Data in Table 3 showed that vegetative growth parameters, i.e. plant height, number of branches, number of leaves, plant fresh weight and leaf area were significantly increased gradually as affected by nitrogen application rates from 50 until 150 kg N per feddan in both seasons. The positive effect of N on vegetative growth parameters of eggplant may be explained on the basis of N plays a major role in protein and nucleic acids synthesis and protoplasm formation as well as stimulates the meristamic activity for producing more

tissues and organs (Russel, 1973 and Yagodin, 1984), these results may be due to that N increase leaf chlorophyll content (Bartal *et al.,* 2001). In the same tendency, Fleafel (2005), Balliu *et al* .,*(*2008) and Lima *et al.* (2014) reported that vegetative growth parameters of eggplant were increased with the increment of N application rate. With respect to the effect of organic mulch on vegetative growth parameters, the results in Table 3 indicated that all organic mulch treatments significantly increased plant height, number of leaves, number of brunches, plant fresh weight and leaf area per plant compared with bare soil treatment. Plants mulched with rice straw gave the best values compared with wheat straw or dry grass treatment in both seasons. The positive mulch effect may be due to keeping the soil moisture and temperature in favorable range for growth. These results are in agreement with the findings of Carter and Johnson (1988) on eggplant, Thakur *et al.* (2000) on pepper and Shaikh and Fouda (2008) on cucumber. The interaction effect of N rates and organic mulch treatments on the vegetative growth characteristics of eggplant were not significant in both seasons.

TABLE 3. Effect of nitrogen rates, organic mulch and their interaction on vegetative growth parameters of eggplants during late summer seasons of 2013 and 2014.

Treatments		2013 Season					2014 season				
N Rate (kg/fed.)	Organic mulch	Plant height (cm)	No. of leaves	No. of branches	Leaf area (dm^2)	Plant fresh Weight (g)	Plant Height (cm)	No. of leaves	No. of branches	Leaf area (cm2)	Plant fresh weight (g)
50		88.1b	171.6b	15.8b	6789.5b	854.3b	86.1b	166.6b	13.8c	6599.7b	844.3b
100		96.4ab	220ab	26.5a	10189.9ab	1078.5ab	93.4b	216.8ab	23.5b	10010.9ab	1063.5ab
150		103.5a	269.9a	28.8a	16184.2a	1297.8a	102.5a	266.9a	27.8a	16002.1a	1277.8a
	Bare soil	90.3b	181.8b	18.2b	7043.0b	808.5b	88.3b	177.8b	16.2b	6900.9b	793.5b
	Rice straw	100.2a	260.8a	27.7a	13292.5a	1258.0a	93.4ab	256.8a	25.7a	13103.7a	1243.5a
	Wheat straw	98.2a	232.8ab	23.7a	11961.8a	1070.0a	96.2a	228.8ab	21.7a	11770.0a	1155.0a
	Dry grass	95.4ab	207.5ab	23.7a	11920.7a	1170.0a	98.2a	203.5ab	23.2a	11709.5a	1055.4a
50	Bare soil	81.2	141.5	11.0	4515.7	653.5	79.2	136.5	9.0	4356.9	643.5
	Rice straw	92.0	209.5	21.5	7949.6	1044.0	84.8	204.5	19.5	7774.4	903.0
	Wheat straw	92.5	162.5	16.5	7169.9	806.7	90.0	168.0	12.0	6965.5	1034.0
	Dry grass	86.8	173.0	14.0	7522.7	913.0	90.5	157.5	14.5	7302.0	796.7
100	Bare soil	91.5	162.0	19.0	5129.5	763.5	88.5	158.0	16.0	5003.0	748.5
	Rice straw	97.5	271.5	31.5	13884.7	1294.5	94.5	244.0	28.5	13660.8	1279.5
	Wheat straw	101.0	248.0	27.5	11979.8	1026.0	92.7	267.5	25.0	11808.6	1215.0
	Dry grass	95.7	201.5	28.0	9765.7	1230.0	98.0	197.5	24.5	9571.4	1011.0
150	Bare soil	98.2	242.0	24.5	11484.3	1008.5	97.2	239.0	23.5	11341.2	988.5
	Rice straw	107.0	325.0	30.0	18043.3	1568.0	100.8	322.0	29.0	17876.0	1548.0
	Wheat straw	107.0	258.5	31.5	16735.6	1378.5	106.0	251.0	28.0	16536.1	1296.0
	Dry grass	101.8	254.0	29.0	18473.6	1236.0	106.0	255.5	30.5	18255.2	1358.5

Values having the same alphabetical letter within each factors and those not having any alphabetical letters (in interaction effect) are not significantly different at the 5% level, according to Duncan's multiple range test.

Fruit yield

Data presented in Table 4 cleared that early and total fruit yields of eggplant were significantly increased by increasing N rate from 50 to 150 kg N per feddan. The highest early and total fruit yields were obtained from the application of 100 and/or 150 kg N per feddan, respectively with no significant effect between them in total yield while the lowest values were related to the lower nitrogen application (50 kg N/ fed.). The positive effect of nitrogen on yield might be due to its stimulating effect on the vegetative growth parameters (Table 3) which form the base for flowering and fruiting (Aminifard *et al.*, 2010). Similar results have been reported by Pal *et al*. (2002), Devi *et al*. (2002) and Amiri *et al*. (2012).

TABLE 4. Effect of nitrogen rates, organic mulch and their interaction on both early and total yield and nitrogen use efficiency during late summer seasons of 2013 and 2014.

Treatments		2013 Season			2014 season		
N Rate (kg/fed.)	Organic mulch	Early yield (ton/fed.)	Total yield (ton/fed.)	NUE	Early yield (ton/fed.)	Total yield (ton/fed.)	NUE
50		13.5b	47.2b	94.5a	13.2b	46.7b	93.4a
100		14.9a	53.3a	53.3b	14.2a	51.1a	51.1b
150		13.4b	54.7a	36.5c	13.2b	52.0a	34.69c
	Bare soil	14.5a	46.7b	54.8b	14.3a	46.6c	55.2c
	Rice straw	14.2ab	54.5a	65.0a	13.2b	51.9a	62.5a
	Wheat straw	13.6ab	52.4a	62.2a	13.3b	50.1b	60.0b
	Dry grass	13.5b	53.4a	63.6a	13.3b	51.1ab	61.1ab
50	Bare soil	13.9	41.3	82.6b	14.2ab	42.3	84.6c
	Rice straw	13.7	50.5	101.1a	12.6e	49.6	99.1a
	Wheat straw	13.6	47.8	95.5a	13.4cd	47.1	94.1a
	Dry grass	12.6	49.4	98.8a	12.6e	47.8	95.6b
100	Bare soil	15.4	48.2	48.2d	14.6a	48.1	48.1e
	Rice straw	15.11	55.8	55.8c	14abc	52.6	52.6d
	Wheat straw	14.9	54.5	54.5c	13.9abc	51.6	51.6d
	Dry grass	14.2	54.7	54.7c	14.2ab	52.1	52.1d
150	Bare soil	14.1	50.7	33.8e	14.0abc	49.3	32.9g
	Rice straw	13.7	57.2d	38.2e	13.1de	53.7	35.8f
	Wheat straw	12.3	54.9	36.6e	13.6bcd	51.6	34.4fg
	Dry grass	13.5	55.9	37.3e	13.1de	53.5	35.7f

Values having the same alphabetical letter within each factors and those not having any alphabetical letters (in interaction effect) are not significantly different at the 5% level, according to Duncan's multiple range test.

On the other hand, Nitrogen use efficiency (NUE) had a negative correlation with the increase of N application rate. Therefore, the highest records were obtained from 50 kg N per feddan while 150 kg had the lowest ones in both seasons. In this concern, Halitligil & Kislal (2002) and Kostadinov & Kostadinova (2014) cleared that there was a negative relation between fresh fruit yield and nitrogen use efficiency.

Concerning the effect of organic mulch treatments on fruit yield, results of mean comparisons in Table 4 showed that the highest early yield was obtained from bare soil compared with organic mulch treatments (Rice straw, wheat straw and dry grass) which had the highest values of total yield and NUE in both seasons. The plants mulched with rice straw had the best results followed by dry grass and wheat straw mulch, respectively compared with bare soil treatment in both seasons.

These results might be due to the fact that, when soil is covered with organic mulch, this led to the moderation of soil temperature (Table 2), reduction of nutrient loss by leaching, conservation of water and weeds management. Similar results were obtained by Thakur *et al*. (2000, 2002) and Law *et al*. (2006) on bell pepper, Moreno *et al*. (2009) on tomato and Pirbonch *et al*. (2012) on eggplant. They found that organic mulch increased fruit yield compared to bare soil treatment. Concerning the interaction effect between nitrogen fertilizer rate and organic mulch treatments on fruit yield of eggplant, no significant differences were observed (Table 4) in both seasons, except for the early yield in the second one, as the interaction was significant. The bare soil treatment with the application of 100 kg N per feddan had the highest early fruit yield followed by bare soil and dry grass with application 50 and 100 kg N per feddan, respectively with no significant differences between both treatments.

Concerning NUE, the effect of combined interaction between N application rate and organic mulch treatments in Table 4 exhibited a significant difference in both seasons. The highest records was obtained from plants fertilized with 50 kg N per feddan and mulched with rice straw. In contrast, bare soil plants fertilized with 150 kg N resulted in the lowest NUE value in both seasons.

Fruit quality

Data in Table 5 revealed that the average fruit weight, fruit length and fruit width were significantly affected by nitrogen application rates in both seasons. The data cleared that the highest values of average fruit weight and fruit length and width were recorded from application of 150 followed by 100 kg N per feddan compared with 50 kg N which had the lowest ones in both seasons. Similar results were obtained by Aujla *et al. (*2007) and Amiri *et al.* (2012)**,** they found that increasing the rate of N application increased fruit length and width. Concerning the organic mulch, data in Table 5 cleared that there were significant differences among treatments on average fruit weight and fruit length and width in both seasons. The highest values of abovementioned parameters were obtained from plants mulched with rice straw followed by wheat straw or dry grass compared with bare soil treatment which had the lowest one in both seasons. The positive effects of organic mulch are confirmed by these of Roberts and Anderson (1994) using wheat straw mulch on pepper, Palada and Davis (2000) using grass straw mulch on pepper, Rodriguez (2007) using rice bran mulch on tomato and Pirbonch *et al*. (2012) on eggplant.

TABLE 5. Effect of nitrogen rates, organic mulch and their interaction on average fruit weight, fruit length and fruit width of eggplants during late summer seasons of 2013 and 2014.

Treatments		2013 Season			2014 season		
N Rate (kg/fed.)	Organic mulch	Av. Fruit Weight (g)	Fruit Length (cm)	Fruit Width (cm)	Av. Fruit Weight (g)	Fruit Length (cm)	Fruit Width (cm)
50		335b	11.4b	11.0b	320.0b	9.4b	10.0ab
100		396.4ab	12.5ab	11.4ab	386.6ab	10.4b	9.5b
150		489.3a	13.1a	12.0a	481.3a	12.1a	10.8a
	Bare soil	378.3c	11.7b	10.7b	367.3c	9.9c	9.1b
	Rice straw	441.1a	13.0a	11.8a	430.1a	11.1ab	10.5a
	Wheat straw	421.3ab	12.8a	11.7a	410.3ab	11.3a	10.4a
	Dry grass	387.2bc	11.8b	11.8a	376.2bc	10.1bc	10.4a
50	Bare soil	287.0f	10.3	10.0	272.0f	8.3	9.0
	Rice straw	353.5e	12.3	11.2	338.5e	10.3	10.2
	Wheat straw	361.0de	12.3	11.5	346.0e	10.3	10.5
	Dry grass	338.5e	10.8	11.3	323.5e	8.8	10.3
100	Bare soil	371.3de	11.8	11.0	361.3de	9.4	8.9
	Rice straw	436.8bc	13.8	11.6	426.8bc	11.1	9.6
	Wheat straw	369.3de	12.3	11.5	359.3de	10.8	9.5
	Dry grass	409.3cd	12.0	11.9	399.3cd	10.1	9.9
150	Bare soil	476.8b	13.0	11.1	468.8b	12.0	9.4
	Rice straw	533.0a	12.9	12.7	525.0a	11.9	11.7
	Wheat straw	533.5a	14.0	12.2	525.5a	13.0	11.2
	Dry grass	413.8cd	12.5	12.1	405.8cd	11.5	11.1

Values having the same alphabetical letter within each factors and those not having any alphabetical letters (in interaction effect) are not significantly different at the 5% level, according to Duncan's multiple range test

The combined interaction between N application rates and organic mulch treatments had no significant effects on fruit length and width and significant effect on average fruit weight in both seasons. The highest value of average fruit weight was obtained from plants fertilized with 150 kg N per feddan and mulched with rice or wheat straw. On the opposite, the lowest one was recorded from the combined interaction between 50 kg N per feddan and bare soil treatment. These results are in harmony with those obtained by Aminifard *et al. (*2010) who reported that there was a positive correlation between average fruit weight and N application rate per feddan.

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استجابة نمو ومحصول الباذنجان للتغطية العضوية والتسميد الازوتى بالعروة الصيفية المتأخرة

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أجريت هذه الدراسة في مزرعة خاصة بقرية الشمارقة ـ محافظة كفر الشيخ خلال الموسم الصيفي المتاخر ٢٠١٣ و ٢٠١٤ م على محصول الباذنجان صنف هجين سواد الليل بهدف دراسة تأثير مستويات التسميد النيتروجينى (٥٠، ١٠٠ و١٥٠ كجم نيتروجين/فدان) ومعاملات تغطية التربة (الملش العضوى: قش الارز، قش القمح، الاعشاب الجافة ومعاملة المقارنة) والتفاعل بينهما على صفات النمو الخضري والمحصول وصفات الجودة لثمار الباذنجان.

ويمكن تلخيص اهم النتائج المتحصل عليها كالآتي:
أعطت زيادة معدلات التسميد النيتروجينى من ٥٠ الى ١٠٠ او ١٥٠ كجم/فدان زيادة معنوية فى صفات النمو الخضرى والممثلة في طول النبات وعدد الاوراق وعدد الافرع و المساحة الورقية والوزن الطازج للنبات وكذلك الصفات المحصولية للمحصول الكلى والمبكر بالاضافة الى جودة الثمار كمتوسط وزن الثمرة وطول الثمرة وعرضها بينما قلة كفاءة استخدام النيتروجين في كلا الموسمين، وعلى الجانب الاخر فان كل معاملات تغطية التربة (الملش) العضوية ادت الى زيادة معنوية فى صفات النمو الخضرى والمحصول وكذلك صفات الجودة للثمار مقارنة بمعاملة المقارنة والتى أعطت أقل النتائج فى كلا الموسمين.

مما سبق يمكن ان نستخلص ان افضل النتائج بالنسبة لصفات النمو الخضري والمحصول وكذلك صفات الجودة لثمارنباتات الباذنجان التى تم تسميدها بمعدل١٠٠ كجم نيتروجين/فدان مع تغطية سطح التربة بمختلف انواع الملش العضوى تحت الدراسة.