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Effect of Farmyard Manure Application on Yield and Some Quality Characteristics of Popcorn (*Zea mays* L. e*verta* Sturt*)* at the Organic Farming

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: It was aimed to determine the effect of different levels of farmyard manure on yield and quality attributes of the popcorn (*Zea mays* L. *everta* Sturt) grown under second crop conditions.
Study Design: The experiment was set up according to randomized complete blocks experimental design with 3 replicates.
Place and Duration of Study: Research was conducted in 2018 under Harran Plain conditions as second crop, Sanliurfa, Turkey.
Methodology: Antcin hybrid popcorn variety was used as a plant material. Farmyard manure (FYM) applications were 0 (control), 1 tone da^{-1} FYM, 2 tone da^{-1} FYM, 3 tone da^{-1} FYM, 4 tone da^{-1} FYM, 5 tone da^{-1} FYM and 6 tone da^{-1} FYM. In study, plant height, stem diameter, grain yield, 1000 kernel weight, popping volume and protein ratio values were researched.
Results: Farmyard manure levels were significant in all tested characteristics. Farmyard manure levels effected positively on plant height (P≤0.05), stem diameter, grain yield, 1000 kernel weight, popping volume and protein ratio (P≤0.01). The highest plant height value was seen 6 tone da^{-1} application of FYM application whereas the lowest plant height value was found at control parcel. Stem diameter value ranged from 19.33 mm (control) to 23.87 mm (5 tone da^{-1} FYM). The highest grain yield value obtained from 6 tone da^{-1} FYM (489.71 kg da^{-1}) while the lowest value was seen

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at control parcel (219.95 kg da^{-1}). But 4, 5 and 6 tone da^{-1} FYM applications were found in same statistical groups. 1000 kernel weight values ranged from 159.60 g to 204.67 g. The highest popping volume value was seen 6 tone da^{-1} FYM treatment. Protein ratio (%) values ranged from % 9.27 to %14.01. The highest protein ratio was obtained from 6 tone da^{-1} FYM while the lowest protein ratio value was found at control parcel.

Conclusion: All farmyard manure levels effected positively on plant height, stem diameter, grain yield, popping volume and protein ratio. The highest grain yield value was seen at 6 tone da^{-1} FYM. But, 4, 5 and 6 tone da^{-1} FYM treatments were in the same statistical groups. There was no statistically significant increase in grain yield after 4 tone da^{-1} farmyard application (478.57 kg da^{-1}). According to research results, considering grain yield, popping volume and protein ratio values, 4 tone da^{-1} farmyard manure was seen sufficient in organic popcorn cultivation.

Keywords: Corn; farmyard manure; grain yield; popping volume; protein ratio.

1. INTRODUCTION

Popcorn (*Zea mays* L. *ssp everta* (Sturt.) is a unique type of flint corn characterized by its ability to pop under heat and become an edible, direct-to-consumer snack product. Unlike dent maize, popcorn kernels are largely composed of vitreous endosperm that spans around the kernel's small, starchy center. This unique morphology, coupled with appropriate moisture content, allows the kernel to expand into light flakes [1]. Popcorn is directly consumed by humans. Its production and consumption at the domestic and international level is rising mostly due to its valuable nutritive characteristics. The market for this popped snack-food has steadily increased for more than a decade. Therefore, the demand for organic popcorn is getting increase day by day.

In conventional agriculture of corn, farmers generally prefer high doses of fertilizers and chemical plant protection measures to realize higher crop yield. Nowadays environmental pollution has reached a significant level as a result of the use of synthetic and chemical inputs in excessive amounts due to the production increase within conventional agriculture system.

But organic production is becoming more important, because of food safety, healthy nutrition, sustainability, positive effects on environmental protection. Organic fertilizers/matters, which are essential inputs of organic agriculture systems that have become widespread in parallel with the interest of people in organic products, are made available for producers under a great variety of names and contents in the market. It is necessary to utilize these matters in various ways to prevent environmental pollution caused by wastes, and to enhance organic matter level of our soil [2].

Fertilizer consumption has reached significant levels by world's population increasing. On the other hand, due to using chemical fertilizers in agriculture, the chemical, physical and biological properties are impaired in the soils. Especially the level of organic matter has fallen below 1%. Various organic materials can be used to eliminate the organic matter deficiency of soils. From the harvest plant residues, farm residues, barn manure, urban residues, industrial waste and similar materials directly or after composting can be used to increase the organic matter content of soils [3].

One of organic materials is farmyard manure which is consists of organic matter and organic residues. In addition to enriching the soil with plant nutrients, it also provides the storage of plant nutrients [4]. The use of farmyard manure is a good organic resource for sustainable agriculture.

Neill and Robinson [5] reported that application of farmyard manure increased grain yield on corn. Negassa et al. reported [6] that the application of FYM alone at rates of 4, 8, and 12 t ha^{-1} produced average grain yields of 5.76, 5.61 and 5.93 t ha^{-1}, respectively, compared to 3.53 t ha^{-1} for the control treatment. Also, a significant residual effects of FYM was emphasized. Tasneem et al. [7] stated that 1000-grain weight and grain yield increased with FYM application to soil.

Leaungvutivirong et al. [8] stressed that various organic materials (like compost, farmyard manure, green manure) increased grain yield and quality of corn rose with application by farmyard manure. Cihangir and Oktem [2] reported that the highest grain yield was obtained from seaweed + cattle fertilizer application at the popcorn. Anung and Purwantono [9] reported that farmyard manure could be used as a source

of nutrients for corn plant, especially in organic cropping systems without using chemical fertilizers.

Najafi et al. [10] carried out a research with FYM at levels of 0, 30 and 60 tons per hectare. Application of FYM increased crude protein concentration and stem height of corn. Application of FYM for corn at the rate of 60 tons per hectare was recommended.

Meena et al. [11] conducted a field experiment to study the effect of organic sources of nutrients on growth, yield, and yield attributes of pop porn. Farmyard manure equivalent to 120 kg N ha^{-1} positively affected corn yield attributes. It was reported that with farmyard manure application plant height, leaf-area index, dry matter, ear length, ear diameter and grain yield was over the control.

Popcorn producers emphasize the use of high-yielding popcorn hybrids, whereas merchants and consumers pay increased attention to the quality of popped kernel, its volume and sensory characteristics. The aim of this study was to determination of different organic farmyard manure levels effect to yield and some quality characteristics such as 1000 kernel weight, popping volume and protein ratio of popcorn.

2. MATERIALS AND METHODS

This study was conducted in 2018, Sanliurfa, Turkey. The experimental area is located in Harran Plain (altitude: 465 m; 370 08' N and 380 46' E) where the climate varies from arid to semi-arid. Table 1 provides the climatic data obtained at the Sanliurfa City Meteorological Station. It is seen on Table 1 that the weather is hot and dry during corn's vegetative duration where maximum temperatures were all above 40 °C while the relative humidity was below 50%. Rainfall was low from June to August in 2018.

Physical and chemical properties of the trial area were determined by taking soil sample from a depth of 0-30 cm on the trial area before planting. The soil of the research field was clay, slightly alkaline, high in lime and very low in salt contents. Field capacity of the soil was 33.8% on dry basis, permanent wilting point was 22.6% and bulk density was 1.41 g cm^{-3}. Some physical and chemical properties of research soil were given in Table 2.

Before the starting of experiment, the trial area was planted with wheat in 2016 and 2017 for making the area suitable for organic farming in which the trial would be established, and wheat was cultivated and harvested without application of any chemical fertilizer and agricultural pesticide.

Antcin hybrid single cross popcorn variety (*Zea mays* L. *everta* Sturt) was used as crop material. Organic certificated farmyard manure was used in the study Organic farmyard manure which included % 0.55 N, % 0.20 P, % 0.45 K and % 0.35 Ca, was used in the research. Farmyard manure levels were control (without farmyard manure and inorganic fertilizer), 1, 2, 3, 4, 5 and 6 kg da^{-1} FMY. All farmyard manure levels were mixed to soil before planting.

Land was ploughed and cultivated then prepared for planting with a single pass of a disk-harrow. The experiment was laid out in a randomize block design with three replications. All organic manure levels were applied to soil with sowing. Each plot area was 14 m^2 (5 m x 2.8 m) and consisted of four rows of 5 m in length. The plants were grown 70 cm apart between the rows with 20 cm spacing in each row (7.1 plants m^2). The seeds were sown at a 50-60 mm depth.

Irrigation water was first applied to all the plots using a sprinkler irrigation system. After the emergence of plants, plots were irrigated equally by the furrow irrigation system throughout the growing period due to lack of moisture in sufficient levels for output. An equal amount of water was given to the parcels. A space of 2 meters was left between parcels to hinder water passage between parcels and the parcels were surrounded with berm. Cultural measures (tractor and hand hoeing) were implemented to combat the weed. Herbicides and insecticides were not used during this study. *Trichogramma* sp. predator was used within scope of biological control against corn cob worm which leads to great productivity losses for corn plants.

In the research, plant height, stem diameter, grain yield, 1000 kernel weight, popping volume and protein ratio values were determined. Firstly, N ratio of kernel was determined and then protein ratio was calculated by multiplying the nitrogen and the 6.25 coefficient.

All tested characteristics, except grain yield were measured on randomly selected 10 plants in the center of each plot. Grain yield values were taken from two rows in the middle of parcel after discarding 0.5 m from both sides of the parcel as edge effect. An analysis-of-variance (ANOVA) was performed to evaluate statistically differences between results. Means of the data obtained from research were compared using least significant difference test (LSD) at $P \leq 0.05$.

Table 1. Monthly climatic data during the corn growth period in 2018 at Sanliurfa

Meteorological observations	Months					
	June	July	August	September	October	November
Ave. Temperature (°C)	28.6	31.9	32.2	28.8	21.6	13.0
Max. Temperature (°C)	43.1	43.2	42.2	41.5	34.2	27.5
Min. Temperature (°C)	16.2	21.2	20.8	17.7	9.3	5.4
Ave. Humidity (%)	36.6	34.2	33.6	31.3	45.6	72.5
Rainfall (mm	10.1	-	-	2.2	39.4	106.6

** Data collected from the Sanliurfa Meteorological Station [12]*

Table 2. Some physical and chemical properties of research soil

Deep (cm)	Organic Material (%)	Total Salt (%)	pH	Lime (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})	Fe (ppm)	Zn (ppm)
0-30	1.26	0.088	7.5	21.4	3.1	94.5	1.04	0.61

3. RESULTS AND DISCUSSION

3.1 Plant Height

Plant height values and LSD groups were given Table 3. As seen in Table 3, according to the results of variance analysis, a statistically significant difference was found between FYM levels in terms of plant height compared to 5%. Plant height values ranged from 130.9 cm (control) to 173.27 cm (6 tone da^{-1} FYM). On the other hand, farmyard manure applications effected positively plant height. Higher plant height values were determined than control plots. Plant height values depend on the growing conditions as well as the genetic structure of the variety. Research results was in accord with some other studies [10,11]. It was reported that plant height varied from 161 cm to 203 cm in for popcorn [13]. Yagmur and Okur [14] reported that farmyard manure applications increased plant height.

3.2 Stem Diameter

According to variance analysis, farmyard manure levels were statistically significant for stem diameter (P≤0.01). The highest stem diameter value obtained from 5 tone da^{-1} FYM level (23.87 mm) while the lowest one was control parcel (19.33 mm). In this study, stem diameter was influenced positively by farm manure applications (Table 3). According to the results of other researches on popcorn; Idikut et al. [15] found that the stem diameter in popcorn varied between 15 mm and 19 mm, while Ozkan [16] found that the stem diameter values varied from 19.1 mm to 21.1 mm. Our results were similar to these researchers' results.

3.3 Grain Yield

Grain yield values and LSD groups were given Table 3. The effect of farmyard manure on grain yield of popcorn was significant (P≤0.01). Control plots had lower grain yield than the organic fertilized plots. The highest grain yield was obtained from application of 6 tone da^{-1} farmyard manure (489.71 kg da^{-1}). But 4, 5 and 6 tone da^{-1} applications of farmyard manure were same statistically groups (Table 3). In the regression analysis, a polynomial curve was obtained between grain yield and FYM levels. A relationship was found between the farmyard manure levels and grain yield at $R^2 = 0.99$ (R^2 denotes the coefficient of determination). The equation of the relationship was $y = -8.5564x^2 + 95.207x + 225.35$. According to regression analysis (Fig. 1) and LSD test (Table 3); there was no statistically significant increase in grain yield after 4 tone da^{-1} farmyard application (478.57 kg da^{-1}). According to research results, 4 tone da^{-1} farmyard manure was seen sufficient in organic popcorn cultivation (Fig. 2). It was stated that farmyard manure application to soil improves soil's structure and nutrient content, as a result of this grain yield may be increased [17]. In this study grain yield values were similar to some researcher's findings. Different researchers reported that farmyard manure treatments positively affected yield on corn [5,6,7,14]. Gajri et al. [18] reported that farmyard manure improved root growth, and the plants extracted soil water more efficiently. Therefore, in the sandy loam

only tillage and farmyard manure increased yields significantly. Delate and Combordella [19], indicated that they obtained 903.1 kg da^{-1} grain yield from organic production while traditional production gave 884.3 kg da^{-1} on corn. Neill and Robinson [5] reported that higher yield obtained with farmyard manure than conventional fertilization.

Table 3. Plant height, stem diameter and grain yield values and LSD groups

Farmyard Manure Levels (tone da^{-1})	Plant Height (cm)*	Stem Diameter (mm)**	Grain Yield (kg da^{-1})**
0 (Control)	130.90 d^{T}	19.33 e	219.95 e
1	148.67 c	20.03 de	324.57 d
2	156.13 c	21.00 cd	376.95 c
3	158.27 bc	21.87 bc	425.12 b
4	173.13 a	23.50 a	478.57 a
5	172.67 ab	23.87 a	483.28 a
6	173.27 a	23.03 ab	489.71 a
LSD	14.57	1.26	30.13

^{T}: Levels not connected by same letter are significantly different
**, **: indicates statistical significances at 0.05 and 0.01 level, respectively*

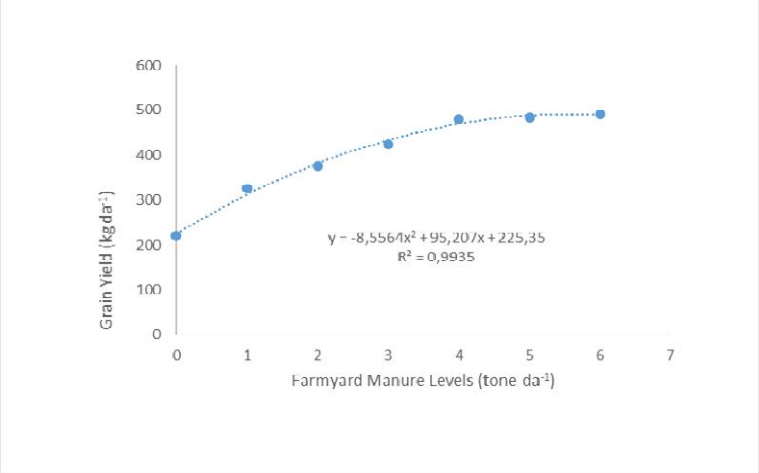

Fig. 1. Regression Analysis between farmyard manure levels and grain yield

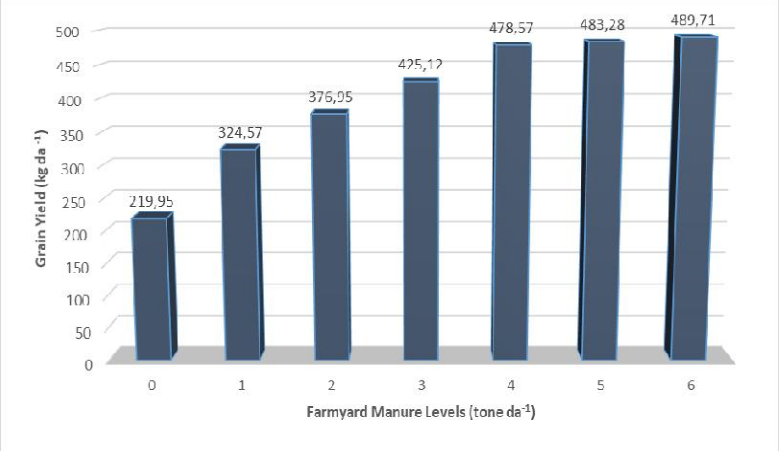

Fig. 2. The grain yield values obtained from the different levels of farmyard manure

3.4 1000 Kernel Weight

According to variance analysis there was significant difference (P≤0.01) on 1000 kernel weight (Table 4). The highest 1000 kernel weight was obtained from application of 6 tone da^{-1} farm manure yard (204.67 g), while the lowest value was found at control parcel (159.60 g). Some researchers emphasized that environmental conditions and genotypes affect thousand grain weight [20,21,22]. In this study, 1000 kernel weigh was effected positively by farmyard manure applications. In this study 1000 kernel weight values were similar to some researcher's findings [20,21,22]. Tasneem et al. [7] stated that 1000 kernel weight increased with FYM application to soil.

3.5 Popping Volume

A statistically significant difference was found between genotypes in terms of compared to 1%. The highest popping volume was seen 6 tone da^{-1} application of FYM (24.43 cm^3 g^{-1}) while the lowest one was obtained from control parcel (18.10 cm^3 g^{-1}). Applications of FYM effected popping volumes positively (Table 4).

Since popcorn is used directly in human nutrition, the grain quality is required. It is especially desired to have a high proportion of popping volume and protein ratio. The large popcorn grain and 1000 grain weight increase the popping volume. It is seen clearly from Table 4 that when the 1000 kernel weight increase, popping volume values also increase. It is reported that popping volume is positively correlated with the 1000 kernel weight [23].

Commercially popping volume is very important, because commercial buyers buy popcorn hybrids by weight and sell the popped corn by volume, thus maximizing final popped volume for given initial popcorn weight maximizes popcorn sellers' profits [24]. High expansion volume is associated with increased kernel tenderness. Also, from a commercial standpoint, popcorn genotypes with high expansion volumes will produce more popped corn than genotypes with low expansion volumes.

Allred-Coyle et al. [25] reported that popping volume depends on seed weight. They determined that popping volume depends on many factors such as size, 1000 kernel weight, moisture contents, test weight, genotype, flake size. Different genotypes and kernel sizes directly affect the popping volume [26]. In the trial, 1000 kernel weight increased, therefore popping volumes increased with FYM applications.

3.6 Protein Ratio

According to variance analysis protein ratio was significant (P≤0.01). The highest protein ratio was found from 6 tone da^{-1} application of farmyard manure, while the lowest value was control parcel (Table 4). Increasing on farmyard manure levels increased protein content of grain. The grain protein ratio, which is one of the important quality parameters, varies according to the variety and environmental conditions. As the nitrogen content increased in 4, 5 and 6 tons of farmyard manure, kernel protein content increased significantly at these fertilizer levels. Kahramanoglu [13] reported that protein ratio values varied from % 11.40 to % 9.30 in the grain. It was stated that the organic fertilizers had an effect positively on the quality of corn [27]. Research results was in accord with some studies that stated protein ratio of popcorn kernel increased with organic farmyard manure [10,11].

Table 4. 1000 kernel weight, popping volume and protein ratio values and LSD groups

Farmyard Manure Levels (tone da^{-1})	1000 Kernel Weight (g) **	Popping Volume (cm^3 g^{-1}) **	Protein Ratio (%)**
0 (Control)	159.60 d[†]	18.10 d	9.27 g
1	184.13 c	19.03 cd	10.60 f
2	185.97 c	19.83 c	11.27 e
3	191.83 b	22.00 b	11.67 d
4	196.33 b	24.17 a	12.60 c
5	202.40 a	24.20 a	13.43 b
6	204.67 a	24.43 a	14.01 a
LSD	5.12	0.99	0.38

[†]: Levels not connected by same letter are significantly different

**, **: indicates statistical significances at 0.05 and 0.01 level, respectively*

4. CONCLUSION

It was seen that farmyard manure effected positively on popcorn yield. The highest grain yield value obtained from 6 tone da^{-1} FYM (489.71 kg da^{-1}) while the lowest value was seen at control parcel (219.95 kg da^{-1}). But 4, 5 and 6 tone da^{-1} FYM was same statistically groups. There was no statistically significant increase in grain yield after 4 tone da^{-1} farmyard application. The highest popping volume value was seen 4 tone da^{-1} FYM treatment. Protein ratio (%) values ranged from % 9.27 to %14.01. The highest protein ratio was obtained from 6 tone da^{-1} FYM while the lowest protein ratio value was found at control parcel. According to research results; considering grain yield, popping volume and protein ratio values, 4 tone da^{-1} farmyard manure was seen sufficient in organic popcorn cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Parsons L, Ren Y, Yobi A, Hurst P, Angelovici R, Rodriguez O and Holding DR. Production and selection of quality protein popcorn hybrids using a novel ranking system and combining ability estimates. Front. Plant Sci. 2020;11;698:1-20. DOI: 10.3389/fpls.2020.00698
2. Cihangir H, Oktem A. Effects of some organic nutrient sources on grain yield of popcorn (*Zea mays* L. *everta*) Journal of Agricultural Sciences. 2018;24:60-71. Turkish.
3. Kutuk C, Cayci G, Baran, Başkan AO, Hartmann R. Effects of beer factory sludge on soil properties and growth of sugar beet (beta vulgaris saccharifera l.). Bioresources Technology. 2003;90:75-80.
4. Gurses MA. The effects of different green manure plants and farmyard manure applications on the yield and yield components of maize (*Zea mays indentata* Sturt.). MSC Thesis. Cukurova University Institute of Natural and Applied Sciences Department of Field Crops; 2020.
5. Neill M, Robinson K. NMSU testing organic alternative to chemical fertilizers. New Mexica State University Research Bulletins. 2001;6:2194-2195.
6. Negassa W, Gebrekidan H, Friesen, K. Integrated use of farmyard manure and NP fertilizers for maize on farmers' fields. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 2005;106(2):131-141.
7. Tasneem K, Mahmood T, Kamal J, Masood A. Effect of integrated use of manure and nitrogen on corn productivity. Int. J. Agri. Biol. 2004;6(2):260-263.
8. Leaungvutivirong C, Sunantapongsuk V, Limtong P, Nakapraves P, Piriyaprin S. Effect of organic fertilizer on soil improvement in Mon, Tha Yang, Satuk and Renuseries for corn cultivation in Thailand. Symposium. 2004;57:1989.
9. Anung TH, Purwantono SD. The use of red-yellow podzolic soil through the application of farm yard manure and EM4 for baby corn development program. Jurnal Pembangunan Pedesaan. 2002;2(2): 1411-925.
10. Najafi N, Mostafai M, Dabagh A, Oustan SH. Effect of intercropping and farmyard manure on the growth, yield and protein concentration of corn, bean and bitter vetch. Journal of Agricultural Science (University of Tabriz). 2013;23(1):1-10.
11. Meena BP, Kumar A, Meena SR, Dhar S, Rana DS, Rana KS. Effect of sources and levels of nutrients on growth and yield behavior of popcorn (*Zea mays*) and potato (Solanum tuberosum) sequence. Indian Journal of Agronomy. 2013;58(4): 474-479.
12. Anonymous, Climatic datas for Sanliurfa. Meteorological Station Bulletin. Sanliurfa. Turkish; 2018.
13. Kahramanoglu Y. Determination of yield and some morphological characteristics of some popcorn genotypes (*Zea mays* L. *everta*) under Harran Plain conditions. Harran University Graduate School of Natural and Applied Sciences Department of Field Crops, Msc Thesis. Sanliurfa; 2019.
14. Yagmur B, Okur B. The Effect of the Some Natural Soil Conditioners on Yield Parameters of Maize (*Zea mays* L.). Ege Univ. Ziraat Fak. Derg. 2018;55(4):471-477.
15. Idikut L, Yilmaz A, Yururdurmaz C, Colkesen M. Investigations on yield performances of local popcorn (*Zea mays* everta) genotypes in the main crop growth conditions. YYU Journal of Agricultural Science. 2012;5(2):63-69. Turkish.

16. Ozkan A. Effects of different nirogen levels on grain yields, agricultural properties and some quality parameters of two popcorn (*Zea mays everta* Sturt.) cultivars under Cukurova conditions. Department of Field Crops Institute of Naturel and Applied Sciences University of Cukurova, phD Thesis: Adana; 2007.
17. Matsi T, Lithourgidis AS, Gagianas AA. Effects of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics. Agronomy Journal. 2003; 95(3):592-596.
18. Gajri PR, Arora VK, Chaudhary MR. Maize growth responses to deep tillage, straw mulching and farmyard manure in coarse textured soils of N.W. India. Soil Use and Management. 1994;10:1(15-19).
19. Delate K, Combardella C. 2000. Comparison of organic and conventional crops at the Nelly-Kinyon Long-Term Agroeciological Research. Iova University. Armstrong Research and Demonstraion Farm Bulletin. 2000;7(4): 208-210.
20. Gokmen S, Sakin MA, Yildirim A. Tokat-Kazova kosullarında yetistirilen bazı cin mısırı (*Zea mays* L. *everta* Sturt) çesitlerinde verim, verim unsurlari ve kalite ozellikleri. Türkiye VII. Tarla Bitkileri Kongresi Erzurum, 25-27 Haziran 2007; 1:330-333. Turkish.
21. Yılmaz I. Tokat-Kazova kosullarında hibrit cin mısırı çesitlerinin (*Zea mays* everta Sturt) yetistirilme olanakları üzerine bir arastırma. GOÜ. Fen Bilimleri Enstitusu, Tarla Bitkileri Ana Bilim Dalı, Msc Thesis.Tokat, 1998. Turkish.
22. Pajic Z, Babic M. Interrelation of popping volume and some agronomic characteristics in popcorn hybrids. Biometrics in Plant Breeding: Proceedings of the Eighth Meeting of the Eucarpia Section Biometrics on Plant Breeding, July 1-6, 1991, Brno: 387-394 Czechoslovakia; 1991.
23. Hallauer AR, Carena MJ, Filho Miranda JB. Quantitative genetics in maize breeding. Springer, New York; 2010.
24. Shimoni E., Dirks E.M. Labuza T.P. The relationship between final popped volume of popcorn and thermal-physical parameters. Lebensmittel-Wissenschaft und Technolgie, 2002;35:93- 98.
25. Allred-Coyle TA, Toma RB, Reiboldt W, Thakur M. Effects of moisture content, hybrid variety, kernel size and microwave wattage on the expansion volume of microwave popcorn. Int. J. of Food Sci. and Nutr. 2000;51:389-394.
26. Ceylan M, Karababa E. Comparison of sensory properties of popcorn from various types and sizes of kernel. J. of the Sci. of Food and Agric. 2001;82(1):127-133.
27. Cengiz R, Yanikoglu S, Sezer M. Cavit. Effects of synthetic and organic fertilizers on maize (*Zea mays* L.).] T.C. Tarim ve Koyisleri Bakanlıgı, Ankara Turkey; 2010. Turkish.

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