AgroLife Scientific Journal - Volume 6, Number 1, 2017
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

PLASTICITY AND ADAPTABILITY OF TUNCELI GARLIC (*Allium tuncelianum* KOLLMAN) UNDER SEMIARID ECOLOGICAL CONDITIONS OF SOUTH-EAST ANATOLIA

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Abstract

Turkey, with important cultural heritage and rich history and enormous plant diversityhas poor agricultural practices that are making difficult to conserve many of the endemic local plant taxon. The soil conservation practices are not sufficient as the farming practices are more often sowing of soil depleting rather conserving. Allium tuncelianum (Kollman) Ozhatay, Matthew & S iranecivernacular "Tuncelisarımsağı" is an endemic specie of garlic native to the Eastern Anatolian province Tunceli, where temperate climate is dominant and the people in general and farmers in particular are not well aware of good farming practices. There is need to develop and introduce more new practical propagation and multiplication approaches for its conservation at naturalhabitat and outside without endangering surrounding environment. This study reports effect of four planting densities andintra-row spacingon some agronomical characteristics of A. tuncelianum yield and some agronomic characteristics. The study was carried under warm semi-arid ecological climatic conditions of Southeast Anatolia ensuring minimum soil depletion effects on the environment. Yield components like plant height, leaf length, leaf width, bulb diameter, flower inflorescence, bulb weight and number of scales onbulb changedsignificantly with range of 101.3-115.8 cm, 37.2-40.4 cm, 2.55-1.61 cm, 3.47-3.85 cm, 8.90-8.87 cm, 36.0-48.1 g and 1.67-1.71 respectively. These values did not show a significant difference with the yield component values at original habitat of the plant at Tunceli. The results of the study are very encouraging and suggest that the plant has large and increased plasticity with easy tolerance and adjustment for differences in climatic without significant loss in yield.

***Key words**: agronomy, bulb size, bulb yield, cultivation, Tunceli garlic, wild plants.*

INTRODUCTION

Turkey lies on cross road to Asia, Africa and Europe and has very important cultural heritage and rich history that is spread all over. This transition has allowed Turkey to develop enormous plant diversity as well with more than 12.057 taxons growing on its soils. These taxons include many of the endemic plant species as well. However, large numberof farmers arenot well aware of good agricultural practices that are making very difficult to conserve both soiland endemic land races of plants (Firat and Tan, 1995). The locally employed soil conservation practices are not adequate, most often and the farming practises are leading to soil depletions on huge scale (Gunal et al., 2015).

No soil protection and poor reclamation work could lead to loss of locally available germplasm to huge scale. As mostof the cultivated land have steep mountainous slopes, farming practices are unsuitable for cultivation. Turkey needs in time, approaches to protect both its soil and fast eroding local germplasm through organised and systematic scientific studies.

The Fertile Crescenten compassing western Iran, Jordan, Syria, Palestine, Israel, Iraq, Lebanon, and southeast Turkey is an area of mega diversity and centre of origin and domestication of many important food, pasture, rangeland, feed, horticultural and medicinal temperate zone plant species (Harlan, 1992). Local land resources are fragile andemphasize importance of maintenance and conservationofbiodiversity without loss of productivity (Held and Cummings, 2014).

The genus *Allium* comprises around 750 species (Stearn, 1992) and issubdivided into 15 subgenera and 72 sections (Friesen et al., 2006; Hirschegger et al., 2010). It is a group of petaloid monocotyledonous genus with bulbs enclosed in fibrous or membranous tunics, which are often or almost tepal free, grow in a subgynobasic way and most of them producecysteine sulphoxides. It has center of diversity located in southwest & Central Asia and North America (Friesen et al., 2006). Many *Allium* species are grown for diverse purposes including their use in foods, in pharmaceutics for their medicinal characteristics (Fritsch and Friesen, 2002) and ornamental purpose that are popular with gardeners (Block, 2010).

A. tuncelianum Kollmanvernacular name "Tuncelisarimsağı" (Kizil et al., 2014) is an endemic garlic specienative to Munzur Mountains (2359 m) largely Ovacik, district of Tunceli province lying between Karasu and Murat dells and limited region lying in between Erzurum and Sivas provinces. It grows competing with other plants in natural environment at its habitat (Figure 1) on soil rich in metamorphic sedimentary volcanic and intrusive rocks (Baktir, 2005). The climate of the region is highly influenced by acold temperate continental climate/Mediterranean continental climate (Dsa) as described under köppen climate classifications (Anonymous, 2016 a, b, c) with extreme winter temperatures and heavy snowfalls. The climate of the area varies from warm to hot and dry during summer. Precipitation in the Munzur Valley and Ovacik district of Tunceli province is variable and ranges between 600-1.000 mm annually, with very little precipitation during summer months. The soils of region areclay loam, sandy clay loam and clay, with pH of 7.0 andwith 1-2% organic matter (TVICOM, 2005).

Figure 1. *Allium tuncellianum* plants growing on metamorphic sedimentary volcanic and intrusive rocks of Munzur Mountains competing with other plants in natural environment

A. tuncelianum contain 1-2 cloves that are locallyused in cuisine for culinary purposeand the cloves could be stored for a long time at 18-20°C. Appropriate agronomic techniques for its culture are still tobe developed. It is locally collected from wild regions for export tobig cities including Istanbul and abroad (European countries); that has been abode to a large number of immigrants from Turkey. Wild populations of *A. tuncelianum* are at a risk of extinction in Turkey, because ofcompetition among neighbouring species, land erosion, human activities like their irrational collection from wild for use in pharmaceutics, and their use for culinary purpose or salad (Kiralan et al., 2013; Aasim, 2015). Increased human activities like construction of houses, highways, cutting of forests, prairies and wilds for farming activities etc. have resulted in rapid or subtle un noticed habitat destruction of *A. tuncelianum*. These activities have also contributed to increased pollution in the area. Cumulative effects of all activities are gradually changing the life style and structure of local people living around the habitat of Tunceli garlic (Pers observations).

Commercially, *Allium* species are propagated either by seeds, cloves or bulbs (De Hertogh and Le Nard, 1993). All plants have different requirements for growth and development. Correct type of soil, planting depth and inter plant space influences uptake of water, nutrition, air, light by plants for growth (Amjad and Ahmad, 2012). However, very limited information is available for successful agronomic culture of *A. tuncelianum* (Kizil and Khawar, 2015). Thus, development of an agronomic technique to conserve and systematically grow Tunceli garlic for obtaining of uniform growth with high yield would be very desirable. It will help to meet ever rising demand of Tunceli garlic for local consumption in foods and industries.

Inthis regard, the study was conducted to determine effects of planting densities on some agronomic characteristics of *A. tuncelianum* under cold semi-arid climatic conditions of the South-Eastern Anatolian plains (BSk according to Köppen classification systems), compared to its habitat at Tunceli province in Eastern Anatolia (Dsa- according to köppen climate classification system), where it grows sparsely under cold temperate climatic conditions (BSk - according to Köppen classification system) on soils rich in metamorphic, volcanic, and sedimentaryrocks (Anonymous, 2016 a, b, c).

MATERIALS AND METHODS

Field studies were conducted under Diyarbakır ecological conditions at the Department of Field Crops, Faculty of Agriculture (latitude 37° 53' N and longitude 40° 16' E, 680 m), Dicle University during 2011-2012 and 2012-2013 growing seasons using bulbs of *A. tuncelianum* purchased from a local producer at Ovacik District of Tunceli, provinceTurkey.

The soil of the experimental area was sandy-loam which was deficient in organic matter (0.41%), available phosphorus (0.17%) and potassium (7.98%), with pH of 8.08. Climatic conditions in the experimental years, with mean temperature, relative humidity and total precipitation from September to July for 2011-12 was 15.4°C, 55.9%, and 625.7 mm, for 2012-13 15.0°C, 54.6%, and 431.6 mm, respectively. Long term with September to July, mean temperature, relative humidity % and total precipitation were 15.3°C, 55.6% and 495.4 mm, respectively (Table 1).

Experimental fields were ploughed to achieve uniform texture and structure and watered three days before planting. The Tunceli garlics were planted in the soil after field capacity of 0.34 bar of suction pressure was established after downward drainage of excess water at the time of planting. No fertilizer was applied before planting or during growth of Tunceli garlic. Planting was done with row spacing of 45 and 70 cm and plant spacing of 10 and 20 cm. The experimental design was a randomized complete block design with three replications for each experimental year with 48 bulbs for 20 cm and 63 bulbs for 10 cm spacing in each plot. Plots size was kept 5.4 m^2 (1.8 m × 3 m) and 8.4 m^2 (2.8 × 3 m) in each of the experiment. Hand planted bulbs at a depth of 5-8 cm had diameter of 2 to 4 cm. The plots were weeded when required. The plots were harvested manually on 5th June, 2012 for the first year and 18th June, 2013 for the second year. Plant height, plant stem diameter, leaf length, leaf width, leaf-less stem length, flower table diameter, bulb diameter, bulb circumference, bulb weight and number of bulbilsper bulb were investigated in the study.

Data obtained in the study were analysed statistically, using MSTAT - C (Michigan State University) computer program, and the means were grouped, using LSD test or t test at 0.05 level of significance.

Table 1. Means of temperature, humidity and precipitation at the site of experimentation for long years, 2012 and 2013 years

Months	Mean temperature (°C)			Humidity (%)			Precipitation (mm)		
	Long Years	2012	2013	Long Years	2012	2013	Long Years	2012	2013
January	2.7	2.4	2.7	78.9	84.5	83.8	70.3	78.3	82.2
February	4.5	2.0	6.1	76.8	68.2	82.3	53.7	74.4	85.2
March	9.0	5.2	9.5	67.4	58.6	62.7	61.1	44.0	19.8
April	14.1	15.2	14.5	66.0	58.4	63.6	64.3	26.2	39.4
May	19.2	19.6	19.0	56.4	58.2	61.7	57.9	41.0	98.0
June	26.1	27.6	26.7	31.7	28.0	27.6	10.6	7.0	2.8
July	30.9	31.2	31.2	22.9	21.1	19.4	0.5	1.6	0
August	30.1	31.0	30.4	20.8	20.9	19.0	0.0	0	0
September	25.0	26.1	24.5	29.7	23.3	25.0	6.5	1.8	0.0
October	17.8	18.5	17.0	47.6	55.1	28.1	50.1	107.4	0.0
November	9.8	12.0	11.4	65.2	77.3	68.8	53.0	83.2	53.8
December	4.5	5.1	-3.4	78.9	85.4	83.6	67.4	160.8	50.4
Mean	**16.1**	**16.3**	**15.8**	**53.5**	**53.3**	**52.1**	**495.2**	**625.7**	**431.6**

Source: State Meteorology Institute (Diyarbakir, Turkey)

RESULTS AND DISCUSSIONS

The effect of temperature on *A. tuncelianum* bulb germination and sprouting in the fields were very clear. Allium species, depending on their origin, divided into four types. *A. tuncelianum* germinate over a wide temperature range (5-25 ºC) (De Hertogh and Le Nard, 1993).

Statistical analysis in Table 2 indicated that there was no significant interaction effect between plant densities and years, while main effects of years significantly influenced plant height, stem diameter, leaf length, leaf width and plant densities that influenced leaf width.

Table 2. Results of analysis of variance and F values of the investigated characteristicsof *A. tuncelianum*

Source of Variance	Plant height (cm)	Stem diameter (cm)	Leaf Length (cm)	Leaf width (cm)	Scape length (cm)	Flower diameter (cm)	Bulb diameter (cm)	Bulb circumfe rence (cm)	Bulb weight (cm)	Number of scale bulb
Years	101.24**	8.58*	9.41*	69.41**	39.44**	0.02	2.09	0.88	38.58**	19.79*
Plant densities	2.35^{ns}	0.78	2.16	10.68**	3.43	6.25**	9.97**	2.96	8.38**	2.01
Interaction	1.92	0.30	2.08	2.47	2.16	5.08*	7.12**	2.99	5.11*	2.36

*Significant at 0.05 probability level; ** Significant at 0.01 probability level; ns non-significant

Figure 2. *Allium tuncellianum* presents healthy plants in the fields showing no signs of stress in the new semi-arid climate of Diyarbakır

All bulbs developed healthy plants in the fields showing no signs of stress in the new semi-arid climate of Diyarbakır (Figure 2). Mean plant height for first experimental year was 101.3 cm, while it remained 115.8 cm during second year. This showed that more precipitation at active growing periods of *A. tuncelianum* during 2nd year of growth influenced plant height positively. A normal vertical crop with no lodging or bending of plants was noted during experimentation avoiding loss of yield showing plasticity of plants with the new environment.

Mean values of plant stem diameter duringfirst year was recorded as 1.26 cm and second year as 1.08 cm, mean values of leaf length was recorded as 37.2 cm during first year and 40.4 cm during second year, and mean values of leaf width were recorded as 2.55 cm during first year and 1.61 cm during second year (Table 3). Increase and decrease in plant density did not influence plant height, stem diameter, leaf length, scape length, bulb circumference and number of scales statistically.

Table 3. Mean values of plant height, plant stem diameter, leaf length and leaf width obtained from different plant densities of *A. tuncelianum*

Planting Densities (cm)	Plant height (cm)			Stem diameter (cm)			Leaf length (cm)			Leaf width (cm)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
45 × 10	100.0	112.6	106.3	1.21	1.00	1.11	38.7	38.9	38.8	2.35	1.37	1.86 C
45 × 20	106.6	114.9	110.8	1.35	1.13	1.24	39.7	41.7	40.7	2.88	1.83	2.36 A
70 × 10	102.7	120.1	111.5	1.26	1.07	1.16	34.0	40.7	37.3	2.26	1.63	1.95 BC
70 × 20	96.0	115.8	106.0	1.20	1.13	1.17	36.5	40.4	38.5	2.71	1.60	2.15 AB
Mean	**101.3 A**	**115.8 B**		**1.26A**	**1.08B**		**37.2 B**	**40.4 A**		**2.55 A**	**1.61 B**	
LSD (0.05)	Years: 9.57			ns			Years: 2.15			Years: 0.20: Plant density: 0.21		

Means within a column followed by the same letter are not significantly different according LSD test at $p \leq 0.05$.

Leaf length andwidth of *A. tuncelianum* are important for improving the bulb; as they affect accumulation of carbohydrate and other essentials necessary for plant growth. Moreover, in the experiment, second year mean value (40.4 cm) was higher compared tothe first year (37.2 cm) values. Conversely, leaf width recorded during first year is higher compared to that recorded during second year (Table 3). Increased precipitation inactive growth periods during first year promoted vegetative growth especially the leaf width compared to leaf length during first year. Low moisture profile during 2nd year promoted elongation in leaves, a cause of moisture stress and reduction in leaf width. This resulted in low leaf area during 2nd year. It is assumed that increased leaf area during first year along with increased width resulted in interception of more solar energy for photosynthesis had positive bearing on all growth parameters according to the findings of Richards (2000).

The differences between scapes (is a long leafless internode forming the basal part or the whole of a peduncle in garlic) lengths were statistically significant. A significant interaction was noted between planting densities and interaction of year × planting densities for flower table diameter and bulb diameter. Mean values of scape length were determined as 76.9 cm during first experimental year and it was measured 84.6 cm during second year (Table 4).

Table 4. Mean values of stem length, flower table diameter and bulb diameter obtained from different plant densities of *A. tuncelianum*

Planting Densities (cm)	Scape length (cm)			Flower table diameter (cm)			Bulb diameter (cm)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
45 × 10	77.6	83.5	80.6	8.67 bcd	8.60 cd	8.63	3.73 a	3.73 ab	3.79
45 × 20	83.6	85.1	84.4	8.27 d	8.97 bc	8.62	4.28 a	4.00 a	4.14
70 × 10	75.1	88.5	81.8	9.49 a	8.97 bc	9.23	2.60 c	3.77 ab	3.18
70 × 20	71.3	81.6	76.5	9.15 ab	8.83 bc	8.99	3.27 b	3.90 a	3.58
Ort.	**76.9 B**	**84.6 A**		**8.90**	**8.87**		**3.47**	**3.85**	
LSD (0.05)	Years: 3.59			İnt.: 0.52			Int.: 0.55		

Means within a column followed by the same letter are not significantly different according LSD test at $P \leq 0.05$.

It was assumed that these differences were due to bulb diameter at planting and differences of precipitation received during experimental years. In respect to flowering table diameter, the maximum table diameter of 9.49 cm was obtained from plants in the scheme of 70 × 10 cm plant spacing during first experimental year, while the minimum table diameter of 8.60 cm was noted on 45 × 10 cm planting density during second year. No statistical difference was noted between years for table diameter. In the experiment, mean values of bulb diameter changed between 2.60 cm and 4.28 cm. The maximum bulb diameter was obtained from 45 × 20 cm plant density during first year, while the minimum bulb diameter was obtained from 70 × 10 cm density during first year of experiment (Table 4).

The higher yield and better control of over or under sized bulbs could be obtained if plants are grown at optimum (45 × 20 cm plant spacing) density. Bulb neck diameter, mean bulb weight and plant height decreased as population density of the plants increased. Total bulb yield could be increased as population density increases and depends on plant species (Kantona et al., 2003).

Only 10% of the whole Tunceli region (the natural habitat of Tunceli garlic) is arable with approximately 9% allocated to wheat, barley and rest to industrial crops like cotton, tobacco and sugar beets, small crops and vegetables. Moreover, rapid urbanization and rural depopulation; mainly due to economic reasons marketing problem and poor cropping pattern, lack of land and poor agronomic practices used by farmers are major problems at habitat. This has led local people towards scattered animal farming. Primarily, owing to these reasons, no agronomic trial has been conducted for Tunceli garlic at habitat or other places forquality bulb production.

Table 5. Mean values of bulb circumference, bulb weight and number of scale bulb obtained from different plant densities of *A. tuncelianum*

Planting Densities (cm)	Bulb circumference (cm)			Bulb weight (g)			Number of scale bulb		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
45 × 10	14.52	14.07	14.52	35.7 bc	37.2 bc	36.5	2.53	1.27	1.90
45 × 20	17.13	17.10	17.13	39.2 b	51.6 a	45.4	2.40	2.00	2.20
70 × 10	25.63	16.20	20.92	30.2 c	49.1 a	39.6	2.67	1.87	2.27
70 × 20	12.77	17.53	15.15	39.0 b	54.5 a	46.8	3.07	1.70	2.38
Mean	**17.51**	**16.22**		**36.0**	**48.1**		**2.67 A***	**1.71 B**	
LSD (0.05)	ns			Int.: 7.30			Years: 1.51		

Means within a column followed by the same letter are not significantly different according LSD test at $P \leq 0.05$.

Bulb circumference was determined as 17.51 cm duringfirst year and 16.22 cm during the second year. Although average temperature during both years of study was almost similar, a reduced precipitation was noted during 2nd year of experiment (Table 5). This had influenced the bulb circumference. The bulbs failed to gather necessary nutrients for their growth, affecting growth of leaves with poor photosynthesis due to reduced accumulation of carbohydrates. This showed that Tunceli garlic circumference was clearly affected by amount of precipitation that supposedly affected regulation and accumulation of starch/sugar ratio and bulb circumference. The results are according to Miko et al. (2000), findings, stating that reduced soil moisture at high temperatures induced reduction of 60% yield. It may be mentioned that garlic has a relatively shallow root system. Among plant densities, bulb length mean values changed between 14.07 and 17.53 cm. The maximum bulb circumference was obtained using widest spacing. So many studies have revealed correlation between sugars content of bulbs and storage temperature in the field and *in vitro* conditions (Salama et al., 1990; Iraqi et al., 2005). The storage of garlic bulbs in cold environment eliminates dormancy and stimulates sprouting.

An investigation of biochemical variation correlated to carbohydrate metabolism is of importance, due tochanges of chlorophyll, carbohydrate contents, amylase and invertase enzymes activity during stratification. Kahsay et al. (2013) observed thatthe narrowest intra-row spacing results indecreased bulb length.When intra-row spacing is increased from 5 to 10 cm, bulb length also increased from 4.1 to 4.6 cm (Table 5). This can be explained by intra row spacing or distribution, structure, and abundance of coexisting plants in population. Interaction of these determine the growth behaviour of plants, including productivity. The pattern of this competition in fluences availability of nutrients and moisture needed for growth. This helps in increased storage of carbohydrates in bulbs in the form of sucrose and more complex oligosaccharides (mainly fructans with various degrees of polymerisation) with improved bulb diameter/circumference/weight. This clearly indicate that competition for nutrients in soil is increased in narrow intra row spacing and decreased in wide intra row spacing. Moreover, their availability to plants was more during first year with more precipitation. Ahmed et al. (2007) observed that increased moisture level in soil at irrigation interval of 3 days had positive effects on number of leaves per plant, plant height at maturity, bulb yield, bulb weight. An increase in irrigation intervals decreased soil moisture content and had negative effects on growth, yield and other components of garlic development.

The maximum bulb weight was obtained from plant densities of 70 × 20 cm intra row spacing, while the minimum bulb weight was observed on 70 × 10 cm intra row spacing during first year (Table 5). Bulb weight was affected by density of plant population and had relationship with the percentage light interception by the *A. tuncelianum* leaf canopy (Addai and Scott, 2011). The importance of optimisation results in two advantages of avoiding competition among plants and allows sufficient space for growthby fetching optimum amount of water, nutrients and light for efficient growth of Tunceli garlic (Awas et al., 2010). The results are in line with Kantona et al. (2003), whonoticedonion yield increase from 17.4 to 39.5 tha^{-1} when plant population per square meter was increased from 50 to 150. Conversely, Rekowska and Skupien (2007) reported higher yield of bulbs and green leaves of garlic from narrowintra-row spacing.

Moreover, *A. tuncelianum* develops as a single cloveand do not constitute any bulbs except over riding bulbilson the cloves that acts as a potential propagules. These are capable to grow into a complete plant subject to cultural practices. Number of overriding bulbils changed depending on bulb size. Three of four over riding bulbils were noted onlarger bulbs, whereas, one overriding bulbil was induced on smaller bulbs in general. Maximum number of overriding bulbils was determined as 2.67 during first year and 1.71 during the second year (Table 5). Bulbs planted in any sowing pattern induced large number of viable seeds (Figure 3). Again induction of larger bulbils during first year with more precipitation seemed to be influenced by the soil moisture regime during first and 2nd years.

There are no reported scientific studies about agronomic yield in natural habitat of Tunceli garlic. Crude estimated yield at its habitat has range of 6500-9590 kg.ha^{-1} (Tunceli Sarımsagı, 2016). However, the results of the study suggests that *A. tuncelianum* has great plasticity and could be successfully grown for economic and commercial production by planting outside cold and temperate climate of its natural habitat to hot semi-arid ecological conditions successfully. This suggests that the plant has large plasticity to changes in ecological conditions with more likelihood tosurvivein other novel environmental and climatic conditions. It is well known that plasticity and level of tolerance to changing environmental conditions will influence in future natural selection and effect diversification among plant species (Sultan, 2004; Scheiner, 1998) that promote adaptive diversity (Sultan, 2004; Pigliucci and Murren, 2003). However, it should be known that besides phenotypic plasticity, genetic adaptationhave definite role in persistence of plant species under new environment (Richter et al., 2012) and thereby conservation of new plant species.

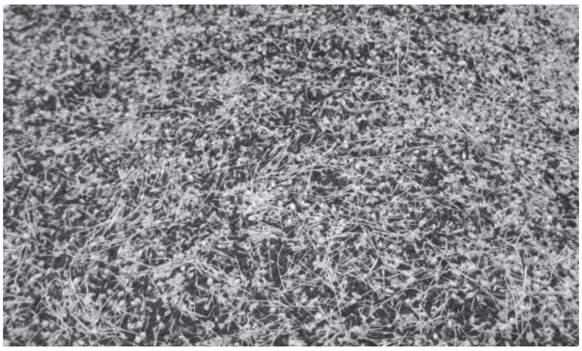

Figure 3. Seeds harvested from growing plants under semi-arid conditions of Diyarbakır

CONCLUSIONS

It follows from the above discussion that Tunceli garlic could adjust itself in semiarid environment that offers new avenues for multiplication adaptability and improvement through breeding. It will be desired to carry out adaptation studies at other places and climates for better comparison and understanding of the plant. Designing of experiments relating to fertilization and irrigation could further help in improving Tunceli garlic yield under semi-arid conditions.

ACKNOWLEDGEMENTS

This work was supported by a grant (Project number: 110 O 703) from the Scientific and Technical Research Council of Turkey (TUBITAK).

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