ARTICLE IN PRESS

Saudi Journal of Biological Sciences xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Grafting improves cucumber water stress tolerance in Saudi Arabia

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ARTICLE INFO

Article history:
Received 28 October 2016
Revised 17 October 2017
Accepted 23 October 2017
Available online xxxx

Keywords:
Cucumber
Grafting
Saudi Arabia
Water stress
Surface drip irrigation

ABSTRACT

Water scarcity is a major limiting factor for crop productivity in arid and semi-arid areas. Grafting elite commercial cultivars onto selected vigorous rootstocks is considered as a useful strategy to alleviate the impact of environmental stresses. This study aims to investigate the feasibility of using grafting to improve fruit yield and quality of cucumber under water stress conditions. Alosama F_1 cucumber cultivar (*Cucumis sativus* L.) was grafted onto Affyne (*Cucumis sativus* L.) and Shintoza A90 (*Cucurbitamaxima* × *C. moschata*) rootstocks. Non-grafted plants were used as control. All genotypes were grown under three surface drip irrigation regimes: 50%, 75% and 100% of the crop evapotranspiration (ETc), which represent high-water stress, moderate-water stress and non-water stress conditions, respectively. Yield and fruit quality traits were analyzed and assessed. In comparison to the non-grafted plants, the best grafting treatment under water stress was Alosama F_1 grafted onto Shintoza A90 rootstock. It had an overall improved yield and fruit quality under water stress owing to an increase in the total fruit yield by 27%, from 4.815 kg plant^{-1} in non-grafted treatment to 6.149 kg plant^{-1} in grafted treatment under moderate -water stress, total soluble solid contents (13%), titratable acidity (39%) and vitamin C (33%). The soil water contents were low in soil surface and increase gradually with soil depth, while salt distribution showed an adverse trend. The positive effects of grafting on plant growth, productivity, and water use efficiency support this strategy as an useful tool for improving water stress tolerance in greenhouse grown cucumber in Saudi Arabia.

1. Introduction

Environmental stresses represent the most important limiting conditions for horticultural productivity and plant exploitation worldwide. Plant species adapt to this adverse condition in different ways. Some plants can (a) complete their life cycle under optimum conditions, (b) reduce water loss by reducing leaf size or stomata pores, (c) maintain growth even during water deficit by retaining water content, or (d) increase water use efficiency (WUE) with limited available water (Bressan et al., 2002).

Grafting elite commercial cultivars onto selected vigorous rootstocks is a special method of adapting plants to counteract environmental stresses (Lee and Oda, 2003). Grafting is currently regarded as a rapid alternative tool to the relatively slow breeding methodology for increasing the environmental-stress tolerance of fruiting vegetables (Flores et al., 2010). Potential approach to reduce losses in production and improve water use efficiency under drought conditions in high-yielding genotypes would be to graft these varieties onto proper rootstocks capable of reducing the effect of water stress on the shoot and to increase tolerance to abiotic stresses (Keatinge et al. 2014).

Cucumber (*Cucumis sativus* L.) is one of the main greenhouse vegetable crops widely grown in Saudi Arabia. The total greenhouse area for cucumber production in 2013 was 2605 hectares produced 236,087 tons (Ministry of Agriculture, 2014). Major factor influencing growth and yield of cucumber is water quantity. Nuysal et al. (2010) studied the effects of different rootstocks on plant growth, yield, fruit quality and water consumption in cucumber. The highest yield was obtained from Nun 9075 (19.02 kg m^2), which was 24.5 and 23.5% higher than in the non-grafted and self-

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Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2017.10.025
1319-562X/© 2017 Published by Elsevier B.V. on behalf of King Saud University.

grafted treatments, respectively. The plant height also increased with the use of rootstocks. The increase in the dry weights of the leaves and fruits depended on rootstocks. They concluded that grafting improved plant growth and yield depending on the rootstock genotype.

Grafting has the potential to be as a strategy to increase the tolerance of plants to promote water use efficiency (WUE) (Öztekin et al., 2007). Therefore, this study aims to investigate the feasibility of using grafting to improve fruit yield, fruit quality and WUE of cucumber under water stress conditions in Saudi Arabia.

2. Materials and methods

2.1. Experimental site and plant materials

Two greenhouse experiments were conducted during the 2014 and 2015 seasons at the Agricultural Research and Experimental Station, Faculty of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia. Responses of commercial cultivar of cucumber grafted on two different rootstocks to water stress (drought) was investigated using three surface drip irrigation regimes: 50%, 75% and 100% of the crop evapotranspiration (ETc), which represent high-water stress, moderate-water stress and non-water stress conditions, respectively. The same irrigation set time and irrigation frequency were applied for each treatment, but different irrigation rate were obtained by using different emitters rate.

2.2. Grafting and water stress treatments

Alosama F1 cucumber cultivar (*Cucumis sativus* L.) was used as a scion while Affyne (*Cucumis sativus* L.) and Shintoza (*Cucurbitamaxima* × *Cucurbita. moschata*) genotypes were used as rootstocks. Non-grafted plants were used as control. Plastic tube grafting was applied to seedlings, when the scions had 2 true leaves and the rootstock had 2–3 true leaves. Rootstocks were cut at a slant and scions were cut by the same way. Grafted seedlings were kept for 5 days under controlled conditions (90–95% RH, 24–26 °C and 45% shading) to enhance the survival rate. Non-grafted seedlings (control plants) were produced at the same nursery under identical conditions and were planted in the greenhouse at the same time.

The seeds of the cucumber genotypes were sown in seedling trays on 10/1/2014 and 3/9/2015 for the first and second seasons, respectively. Seven-day-old grafts of the cultivars onto their rootstocks were performed. Ten days-old seedlings transplanted onto soil in the fiberglass greenhouse.

The temperature and relative humidity was set to approximately 27 ± 0.5 °C and 80 ± 2%, during the growth. Fertilization and other cultural practices was applied as commonly recommended in commercial cucumber production. The soil texture was determined, and a mechanical soil analysis was conducted and presented in Table 1.

The quantity of irrigation water supplied was scheduled based on the crop evapotranspiration (ETc) calculated using the Penman Monteith equation with data from the meteorological station near the study area matched with the crop coefficient values of the cucumber in the region. The irrigation water was applied at a target rate of 50%, 75% and 100% ETc, using drippers with different irrigation rate (4, 6 and 8 liter per hour). Drip tubing (GR type, 16 mm diameter) with 50 cm emitter spacing built in was used in irrigation as described in (Al-Harbi et al., 2017).

The field water productivity (also known as WUE, which is the relationship between crop yield and water applied was calculated using Eq. (1), expressed as kg/m^2 or Ton/ha.

$$\mathrm{WUE} = \mathrm{Yield}\ (\mathrm{Kg, ton})/\mathrm{Water\ Applied}\ \ (\mathrm{m}^3).$$

2.3. Experimental layout

The experimental layout was a split plot in a randomized complete block design with four replications. The water stress treatments were randomly allocated to the main plots, whereas the grafting treatments were arranged in the sub-plots. The planting distance was 50 and 100 cm between plants and rows, respectively.

2.4. Measurement of traits

Random samples of four plants from each experimental unit were chosen at 45 days after transplanting to measure vegetative growth traits. Vine fresh and dry weights were measured. Vine dry weight samples (each about 50 g) were determined by drying at 70 °C until constant weight, using a forced-air oven. Total yield (all the collected fruits) was determined. Samples of five ripe fruits (from the third-fourth trusses) representing each sub-plot were picked for analysis of the fruit quality traits; total soluble solids (TSS, %), vitamin C (mg 100 g^{-1} fw) and titratable acidity (TA, %). An extract was obtained by blending and filtering flesh of each fruit sample. TSS (%) was deliberated using a digital refractometer (PR-101 model, ATAGO, Japan). For determination of TA, 10 g of extracted juice was taken and carefully mixed with 50 ml of distilled water. The mixture was then titrated by 0.1 N NaOH until a pH value reached 8.1. The volume of the sodium hydroxide added to the solution, was multiplied by a correction factor of 0.064 to estimate TA as the percentage of citric acid equivalents in the fruit juice (Turhan and Seniz, 2009). Vitamin C (mg 100 g^{-1} fw, as ascorbic acid) was measured in cucumber extract using 2, 6 dichlorophenol-indophenol dye (Patane et al., 2011).

Sampling locations for both soil water content and soil salinity were 0.15 m from the plant at the soil surface and 0.15 m depth intervals down to 0.60 m depth. The electrical conductivity of saturated extract (ECe, dS/m) was determined for each sample then

Table 1
Some physical and chemical characteristics of experimental soil.

Parameters	Soil depth, cm			
	0–15	15–30	30–50	50–70
Particle – size distribution, %				
Sand	93.0	89.0	89.0	89.0
Silt	1.0	6.0	4.0	6.0
Clay	6.0	5.0	7.0	5.0
Textural class	Sand	Sand	Sand	Sand
Organic matter content, %	0.03	0.13	0.16	0.02
$CaCO_3$, %	32.0	27.0	24.0	30.0
Saturation water content, %(w/w)	27.2	28.3	29.3	29.8
Field capacity, %(w/w)	14.8	16.4	17.1	16.8
Permanent wilting point, %(w/w)	6.4	7.2	6.7	6.3
Plant available water, %(w/w)	8.4	9.2	10.4	10.5
pH	7.51	7.72	7.92	8.05
Electrical conductivity (EC_e dS/m)	2.75	2.65	2.00	1.80
Soluble cations, me/L				
Ca^{2+}	16.4	11.1	11.1	9.1
Mg^{2+}	6.0	6.7	5.6	5.0
Na^+	11.0	14.4	6.5	6.4
K^+	1.5	2.1	1.7	1.5
Soluble anions, me/L				
$CO_3^=$	Tr.	Tr.	Tr.	Tr.
HCO_3^-	3.9	4.0	2.0	4.0
Cl^-	9.8	10.5	7.0	5.0
$SO_4^=$	12.8	13.9	10.9	8.7
SAR	3.29	4.83	2.18	2.41