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The effect of planting methods on maize growth and yield at different irrigation regimes

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ABSTRACT- Maize production, which is ranked after wheat and barely in Fars province, Iran, needs a considerable amount of irrigation water that is not available in scarce water conditions in drought situations. Therefore, proper planting method can improve irrigation water management. The objectives of the present study were to investigate the effects of two planting methods, on-bed and in furrow bottom, on maize growth and yield, and also on soil water content in root zone at different irrigation regimes in a semi-arid condition. The results can be used for improving or designing appropriate machinery maize cropping in-bottom of furrows. Experimental treatments were applied: water at amounts of 60, 80 and 100% of crop evapotranspiraton (ET_c), and two planting methods on-bed and in-bottom of furrow were used. The experiment was conducted and analysed in a split-plot design with three replications. Results revealed that the irrigation regimes and planting methods had significant effects on grain yield and total dry matter of maize. The irrigation regime of 80% of ET_c with planting in-bottom resulted in highest grain yield (8193 kg ha^{-1}) and water use efficiency (1.05 kg m^{-3}). Although the highest yield was obtained for in-bottom planting, the restricted root growth observed may be due to soil compaction resulting from furrower pressure on the soil. Hence, designing soil tillage tools for reducing the soil compaction beneath the seedbed is recommended for future studies.

INTRODUCTION

Maize is one of the three main world cereals that was originally produced and evolved 7000 to 10000 years ago in Mexico. Maize plant has wide compatibility with different climates, but the rate of its growth is higher at tropical and subtropical climates. Maize grain production is ranked at the fourth place after wheat, barley and rice in Iran. Amongst the provinces, Fars province with the largest maize cultivation area is ranked at the first place. Nearly 26 % of total maize production in Iran is produced in Fars province (Anonymous, 2010).

According to the FAO report (2009), the production of grain maize in Iran was 1.6 million tons while the world production was 818 million tons (Anonymous, 2009). Maize is usually planted on-bed in rows with spacing 75 cm using corn planter. As it is common, the distance between plants on a row is adjusted to 12-25 cm. This crop needs plenty of water for growth and acceptable yield. In recent years, lack of adequate rainfall caused drought conditions in Iran (Khazanehdary et al., 2009). Therefore, an appropriate water management is needed for better crop production.
Crop potential evapotranspiration (ET_p) of the maize is dependent on the local climate, but studies reported that it is about 624 mm for silage maize (MajnooniHeris et al., 2007a), and about 848 mm for grain maize (MajnooniHeris et al., 2007b).

In some researches, different methods of irrigation, i.e., fixed and variable alternate furrow, and conventional furrow (Sepaskhah and Parand, 2006; Du et al., 2010) were studied. ZandParsa and Sepaskhah (2001) noted that in water limiting conditions, the optimum value of applied water is 736 mm. Du et al. (2010) suggested that mild water deficit at early seedling stage is beneficial for maize grain yield and water use efficiency (WUE). They reported that alternate furrow irrigation maintained similar photosynthetic rate but reduced transpiration rate, and thus increased leaf WUE of maize. Sepaskhah and Khajehabdollahi (2005), and Sepaskhah and Parand (2006) expressed that maize grain yield and top dry matter have considerably decreased when the plant was irrigated by variable alternate furrow throughout the growing seasons compared to conventional furrow methods with 7-day interval.

The effect of water stress on the yield of maize in different growth stages was shown by other investigators. Herero and Johnson (1981), for instance, stated that water stress had influence on spike and tassel. Kang et al. (2000) found that the grain yield of plants subjected to a water stress at seedling stage was not significantly reduced by a further mild soil drying (55% of field capacity at the minimum) at the stem–elongation stage. That is, it was observed that grain yield of such plants was similar (no significant difference) to those always well-irrigated. In their study, ZandParsa et al. (2006) found that water stress had a significant effect on grain yield of single-cross 704 maize cultivar. Kang et al. (2002) reported that when water consumption was reduced by 20 and 40% through extending the irrigation intervals, the alternate irrigation produced the same amount of biomass production under moderate soil drying (20% water reduction). In addition, the values of WUE and root to shoot ratio were improved by alternate watering.

It was also reported that no-till planting method helps to retain the soil moisture content in the root zone significantly, as compared to conventional tillage system (Kosgei et al., 2007). Thereby, maize yield is higher in no-till planting system than the conventional system. Zhang et al. (2007) carried out an experiment to evaluate the effect of different tillage and planting methods on wheat yield. They found that planting in-bottom of furrow increased the yield about 7.8% more than planting on flat plots. Furthermore, it was found that the water consumption was decreased by 20 % in-bottom planting.

The objective of the present study was to evaluate the planting method of maize, i.e. on-bed and in-bottom of furrow at different irrigation water regimes (60%, 80% and 100% of ET_c) in a semi-arid region of Iran.

MATERIALS AND METHODS

This experiment was carried out in a field with 1800 square meter area in the College of Agriculture, Shiraz University, Shiraz, Iran, located at 29°50 latitude, 52°46 longitude, and 1810 ma ltitude. Soil texture is silty-clay-loam with an average bulk density of 1.43 g cm^{-3}. The field was initially tilled by a mouldboard plow and then pulverized by a disk harrow twice. Between two disk operations, 100 kg ha^{-1}super phosphate was spread on the soil and mixed by disking. In pulverized soil, a leister and bidder created furrows 75 cm apart with an average height of 30 cm. Since uniformity in planting depth was an important factor for the study, a cone puncture with 6 cm in root diameter and 5 cm in height was made and used for creating seed place hole in the soil. Single cross 704 maize seed was used for planting. Seed interval on each row was 22 cm in all plots. Planting was done on-bed and in-bottom of furrow on the 15th of June, 2009.Irrigation was applied at three different levels of 60, 80 and 100% of plant evapotranspiration (ET_c) at a 7-day interval. ET_c was determined by K_c and ET_0 where K_c (values for the initial, mid-, and end-season growth stages of maize were 0.48, 1.40, and 0.31, respectively) and ET_0 are the crop coefficient and reference evapotranspiration, respectively, determined by using weather station data and Penman-Monteith methods (Allen et al., 1998, Shahrokhnia and Sepaskhah, 2013). Urea fertilizer was distributed twice (2009/7/15 and 2009/8/17) after seed planting at the rate of 150 kg ha^{-1}. Weeds were manually controlled twice.

Experiments were carried out and analyzed in a split-plot design with three replications. Main plots and split plots were respectively assigned to the value of applied water and planting position. Plot dimensions were nearly 3 by 7 m. The first and second irrigations were applied after planting on the 18th of June, 2009 with a value of 100 mm uniformly for all plots. Afterward, all irrigations were carried out according to the assigned treatments. The quantity of irrigation water was determined based on Penman-Monteithequation by considering meteorological data for the study region which were collected by the Department of Irrigation, Shiraz University. An irrigation system consisting of an electro-pump set and pipe lines was used to control the volume of applied water. The flow of water was calibrated using a stopwatch and volumetric container five times before each irrigation event.

Plant attributes such as total (above ground or top) dry matter and plant height were measured every three weeks till the harvest time. Two plants were taken from each plot; totally 6 plants were taken for the aforementioned measurements. The leaf surface area was measured using leaf area meter (Hitachi-KPD40EK, Japan). To do this, all leaves were detached from the stem and exposed to the machine camera. The height of plant was measured from the first node above the root to the top of the stem. After appearing the tassel, the height was measured to the node below it. Harvested samples were weighed by a digital balance with an accuracy ±0.01g. Stems and leaves were cut into 30 cm pieces, wired and labelled. These batches were kept in an oven at 70°C for 48 hours.

Irrigation water was applied weekly till the harvest time. Cumulative seasonal applied irrigation water for 60, 80 and 100% treatments were 570, 760 and 950 mm, respectively. After the harvest, some attributes such as stover (top excluding cob) dry matter (SDM), grain dry matter and cob weight, plant height and grain moisture content were determined. The initial grain moisture content was 57.2±7.0 on w. b. Maize grain yield was presented based on grain dry matter.

Gathered data were analyzed according to the split-split plot design and mean values were compared by Turkey post-test.

RESULTS AND DISCUSSION

About ten days after the first irrigation, the in-bottom planted seeds germinated in all treatments, whereas those which were planted on-bed germinated nearly 7 days later. The aforementioned attributes of plants were measured after the germination of all treatments.

Dry Matter and Grain Yield

The variation of plant dry matter from germination to the harvest time is depicted in Fig. 1. The analysis of variance on final dry matter yield at the harvest showed that it was significantly affected by the planting method (Fig. 2). The highest dry matter was obtained from in-bottom planting method (17620 kg ha^{-1}), whereas it was 14770 kg ha^{-1} for on-bed planting method (Fig. 2). Different amounts of applied water had no statistically significant effect on total dry matter of maize; however, the lower value was obtained at 60% irrigation treatment (14300 kg ha^{-1}), followed by 80% irrigation (17780 kg ha^{-1}), and 100% (16500 kg ha^{-1}). Furthermore, no interaction was observed between planting and irrigation methods.

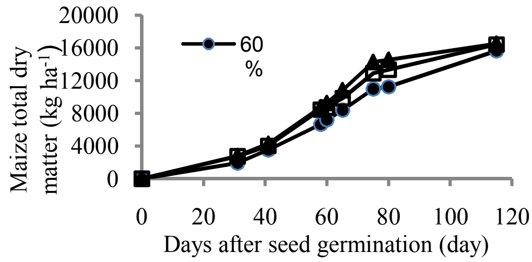

Fig. 1. Total dry matter of maize during the growth period (till harvest)

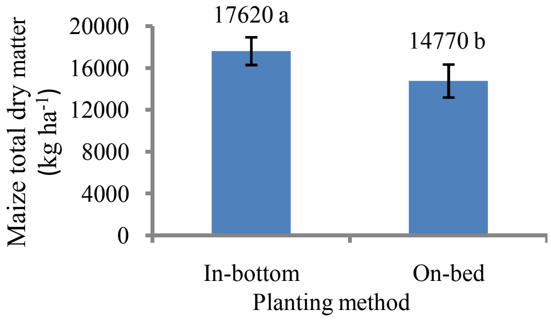

Fig. 2. Total dry matter of maize at different planting methods

Final stover dry matter (SDM) and grain yield were analyzed, separately. It was found that different irrigation treatments had a significant effect on SDM and grain yield (Figs. 3 and 4). Minimum grain yield was obtained in plots of 60% and maximum was in plots of 80% and 100 % irrigation treatments. Results revealed that in-bottom planting plants could absorb more soil water and used it to produce greater dry matter. As shown in Fig. 4, there was a statistically significant difference between the two planting methods.

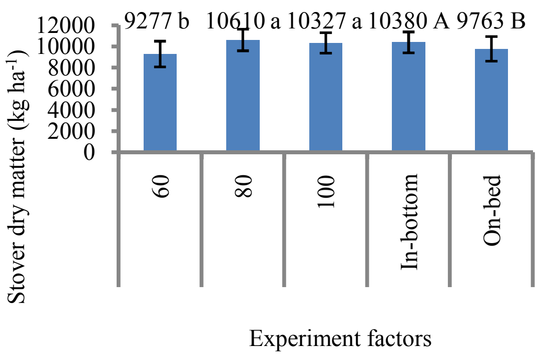

Fig. 3. The effect of different main factors on stover dry matter of maize

An interaction effect between the value of applied water and planting method on grain yield was found ($p<0.05$). According to Fig. 5, the supreme grain yield was obtained for in-bottom planting and irrigation with 80% water requirement followed by 100% and 60% irrigation treatments. Additionally, there was a statistically significant difference between 60% water requirement and 80 % water requirement treatments for both planting methods. Although reaching the highest grain yield was desired, the plants in-bottom planting could not extend their roots as compared to on-bed planted plants (Fig. 6).

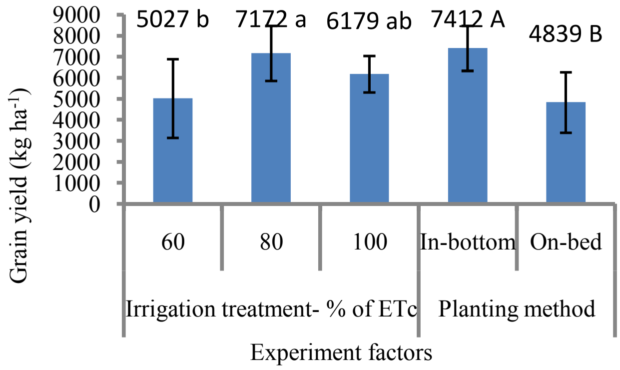

Fig. 4. The effect of different main factors on maize grain yield

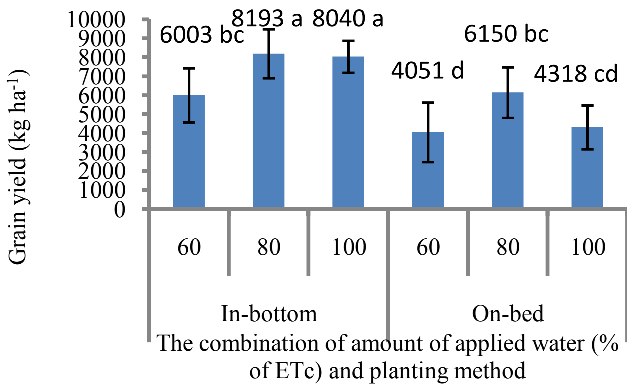

Fig. 5. The interaction effect of the amount of applied water and planting method on maize grain yield

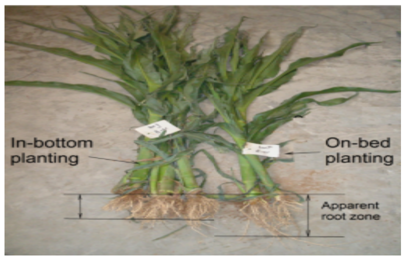

Fig. 6. A comparison between root heights of plantsin different planting methods

This might have occurred due to the compaction of the soil beneath the seeds because of opener pressure, or inappropriate depth of soil tillage before planting. The verses of some in-bottom planted plants confirmed that roots had not had enough strength to erect the plant against dry matter increment, wind force and even soil loosening because of irrigation. It can be concluded that for plant root establishment and vertical development, designing or modifying soil tools is necessary and inevitable.

Plant Height

It was observed that both applied water and planting methods affected the plant height at the harvest (Fig. 7). Maximum plant height was 129 cm, 153 cm and 157 cm for 60%, 80% and 100% irrigation regimes, respectively. If forage maize were harvested when grains were in milky stage or even the prior stage, for avoiding any mechanical damage on chopper components especially cutter head knives, the average height of plant from pollination to harvesting was also analyzed. The same trend was observed among the treatments. It was 115 cm, 140 cm and 145 cm for 60%, 80% and 100% irrigation regimes, respectively. In-bottom planting had significantly ($p \leq 0.01$) higher height than on-bed treatments. However, the combination of irrigation regime and planting method resulted in maximum yield for in-bottom planting that was irrigated at 80% and 100% water requirements (Fig. 8).

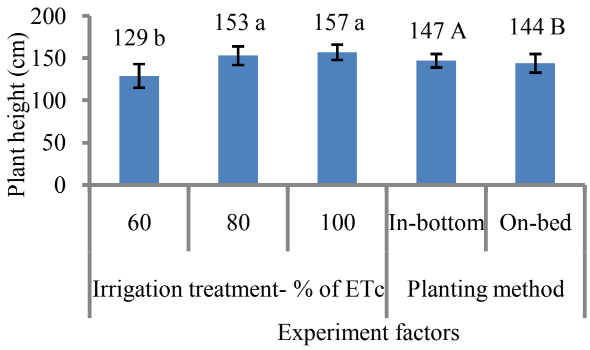

Fig. 7. The effect of different main factors on plant height

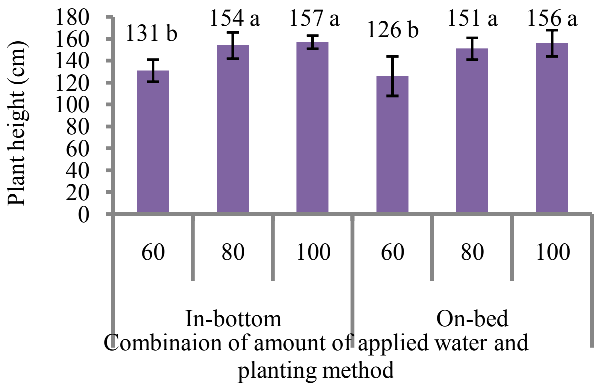

Fig. 8. The interaction effect of the amount of applied water and planting method on plant height

A comparison of dry matter yield and plant height showed that the highest dry matter production and plant height were obtained at 80% and 100% water requirements and planting in-bottom (Figs. 5 and 8). Therefore, 80% water requirement can be recommended for forage maize production. On the other hand, the highest grain yield was obtained at 80% water requirement and in-bottom treatment. It also emphasizes that a combination of 80% applied water and in-bottom planting method can be recommended for both forage and grain production.

Water Use Efficiency

For an informed decision about the appropriate combination of planting method and quantity of irrigation water, the amount of grain yield per unit volume of applied water, as water use efficiency (WUE), was determined. In this study, the applied water was used by crop evapotranspiration. Analysis of variance on WUE showed that it was affected by the planting method (p=0.02). Split-plot design of WUE for irrigation attributed to the main plots did not show any significant difference among treatments at 5% level of significance (p=0.07). However, according to Basiri (2008), the analysis of variance based on complete randomized block design showed a statistically significant difference between irrigation treatments at 1% level of probability (Fig. 9).

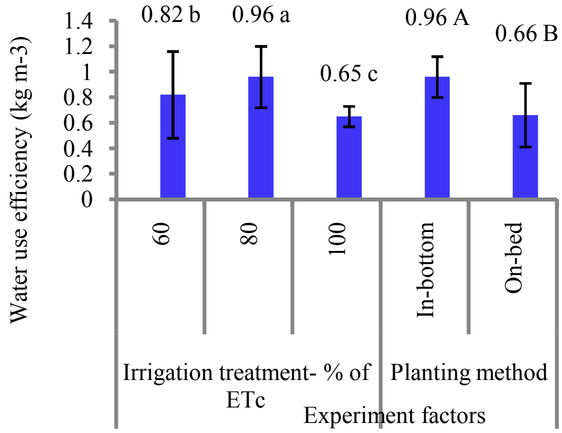

Fig. 9. The effect of different main factors on water use efficiency

English and Nuss (1982) reported that by decreasing applied water, the yield is also decreased, but it would reduce the water extraction, transfer and distribution expenses and finally increase the benefit. Hargreaves and Samani (1984) recommended deficit irrigation as an appropriate alternative to maximize the WUE. It was found that maize kernel growth was relatively unaffected by a water deficit because of high stalk moisture content and translocation from the stalk to the grain (Ouattar et al., 1987). Jaliliyan et al. (2001) in a study on economic benefit of sugar beet production found that although deficit irrigation 80% of plant evapotranspiration decreased the yield from 53 t ha^{-1} to 48 t ha^{-1}, it increased the economic benefit. Sepaskhah et al. (2006) stated that net income per unit water was increased by decreasing in quantity of applied water (optimum water) for both land and water limiting conditions.

Therefore, it can be concluded that maize planting in-bottom and irrigation with 80% of plant water requirement not only did not reduce the yield but also increased the value of WUE (Fig. 10). The in-bottom planting can be recommended and used as an alternative planting method when drought is the prominent situation in a region.

CONCLUSIONS

This research aimed to introduce a new planting method for maize, as one of the important cereals, and water intensive crops. Results revealed that in-bottom of furrow planting could lead grain and vegetative yield beyond the conventional (on-bed) planting method. Moreover, the combination of in-bottom planting and irrigation with 80% plant water requirement distinguished this combination amongst other treatments for higher water use efficiency. Therefore, whenever and wherever drought is the dominant condition, in-bottom planting and the application of water about 80% plant evapotranspiration can be recommended as an alternative planting-irrigation method. It can also be concluded that in-bottom planting needs special tillage tools to guarantee proper plant root development. It is obvious that this new approach of planting dictates further research for developing new planting, controlling and harvesting machines for maize.

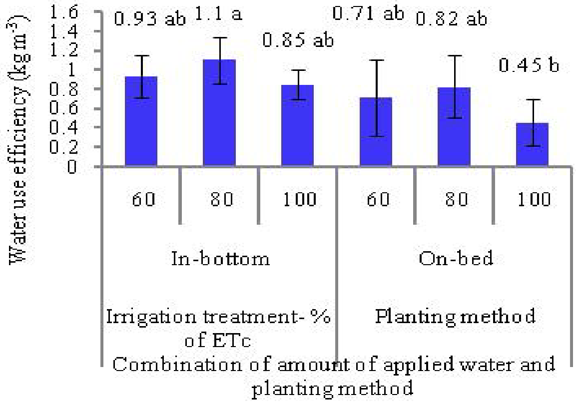

Fig. 10. The interaction effect of the amount of applied water and planting method on water use efficiency

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دانشگاه شیراز

تاثیرروش کشت بر رشد و عملکرد ذرت در رژیم‌های مختلف آبیاری

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بهره‌وری آب آبیاری

ذرت

روش کشت

کارنده

چکیده- تولید ذرت در استان فارس بعد از جو و گندم در مقام سوم قرار گرفته است. این محصول به مقدار قابل ملاحظه‌ای آب آبیاری نیاز دارد که در شرایط کم‌آبی و خشکسالی در دسترس نیست. بنابراین، یک روش کشت صحیح می‌تواند مدیریت آب آبیاری را بهبود بخشد. هدف مطالعه حاضر بررسی تاثیر روش کشت داخل جویچه و روی پشته بر رشد، عملکرد ذرت و محتوای رطوبت خاک در ناحیه ریشه در مقادیر مختلف آب آبیاری در شرایط اقلیمی نیمه‌خشک می‌باشد. نتایج این مطالعه برای اصلاح و طراحی ماشین‌های کاشت، داشت و برداشت ذرت برای کشت در داخل جویچه لازم و ضروری است. تیمارهای این پژوهش شامل مقدار آب آبیاری با مقادیر ۱۰۰، ۸۰ و ۶۰ درصد تبخیر- تعرق، و روش کشت روی پشته و داخل جویچه بود. آزمون ها در قالب طرح کرت‌های خرد شده اجرا و مورد تجزیه و تحلیل قرار گرفت. نتایج نشان داد که رژیم‌های آبیاری و روش کشت بر عملکرد و کل ماده خشک ذرت اثر معنی‌داری داشته است. رژیم آبیاری ۸۰ درصد تبخیر- تعرق با روش کشت داخل جویچه بیشترین عملکرد دانه (۸۱۹۳ کیلوگرم بر هکتار) و *بهره‌وری* آب آبیاری (۱/۰۵ کیلوگرم بر مترمکعب) را بدنبال داشت. اگرچه بیشترین عملکرد در روش کشت داخل جویچه بدست آمد، اما رشد ریشه در اثر سفت شدن خاک کف جوی به علت عبور جویچه ساز محدود شده بود. بنابراین، طراحی ابزار خاکورزی برای سست کردن خاک کف جویچه در زیر بستر بذر برای مطالعات بعدی توصیه می‌شود.