EFFECT OF IRRIGATION METHODS ON GRAIN MAIZE *(Zea mays* L.*)* PRODUCTION

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Agronomy)

Department of Agronomy
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This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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ABSTRACT

Maize is a crop which is very sensitive to water stress. The full potential yield of maize can be attained without water stress throughout the growing season. This study was carried out at the field of the Department of Agronomy, Yezin Agricultural University during November to April in 2017 - 2018 and 2018 - 2019. The objectives of the study were to compare the effects of drip and furrow irrigation methods in maize production, to evaluate yield and agronomic characters of five maize varieties, and to observe the \characters of maize. Main plot factor of irrigation methods (drip irrigation and furrow irrigation) and subplot factor of five maize varieties (SA - 282, NK - 621, NK - 625, LG - 778 and P - 515) were assigned in Split Plot Design with three replications. Drip irrigation gave increased yields in both seasons. This increased yield may be due to increased ear length in the first season and increased ear length and thousand grains weight in the second season. The highest grain yield was obtained from the variety NK - 621 probably due to increased thousand grains weight in the first season, and from the variety SA - 282 probably due to increased number of ear plant^{-1} and shelling percent in the second season. Ear weight and thousand grains weight are very important yield contributing components because of strong and positive correlation with grain yield in both seasons. The responses of varieties varied with irrigation methods in days to 50% tasseling, days to 50% silking, row length, ear length, ear weight and number of ear plant^{-1} in the second season. Although there was no significant interaction effect of irrigation methods and tested varieties on grain yield in both seasons, the highest grain yield was obtained from the variety P - 515 and NK - 621 under drip irrigation in the first season, and from the variety NK - 621 and SA - 282 under drip irrigation in the second season. Drip irrigation can give more profit in long term than furrow irrigation in the dry season of the environment favorable for maize production.

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CHAPTER I
INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop species, after wheat and rice, grown throughout a wide range of climates. It is among the ten most important world crops by value. Maize is desired for its multiple purposes as human food, animal feed and for pharmaceutical and industrial manufacturing (Huang, Birch & George, 2006). As a consequence of these uses, increasing population and economic development, maize grain demand is dramatically increasing. The total number of the world population was 7.6 billion in 2018 (Population Reference Bureau [PRB], 2018). The world population will grow continuously 9 billion in 2050 (PRB, 2014). As the world's population increase and more people begin to include higher amounts of meat, poultry and dairy into their diets. Therefore, maize becomes an important crops for growing population around the world. The world maize production is about 1008 million tons grain from approximately 189.8 million hectares of land (GEOFIN, 2016). In Asia countries, maize production is being increasingly important as the demand for both national needs and export is expanding quickly.

Next to rice, maize stands as the second most important cereal crop in Myanmar, which is used as human consumption, animal feed for livestock farming and as one of the major agricultural products for export and hence more production of maize is needed through expansion of cultivable area and increased production per unit area (Ministry of Agriculture and Irrigation [MoAI], 2014). Maize is a crop which is very sensitive to water stress (Pandey, Maranville, & Chetima, 2000; Cakir, 2004; Kuşçu & Demir, 2012). Payero, Tarkalson, Irmak, Davison, and Petersen (2009) reported that water stress has an effect on growth, development and physiological processes of maize plants, which reduce biomass yield. Because of this, one of the most important factors that can limit crop production is availability of water. If water stress can be avoided during silking and early ear development, high yield could be expected (Karasu, Kuscu, & Oz, 2015).

In Myanmar, the average yield and production of maize in 2017 - 2018 was 3.88 t ha^{-1} and 1.940 MT, respectively, from the total sown area of 504,000 ha and the export of maize in 2017 - 2018 was 1.437 MT (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2018). Maize is cultivated mainly in the country's site of Shan, Chin states and Sagaing, Magway and Mandalay regions as a seasonal crop in monsoon and winter. In 2018, the market price of maize is 206 to 250 MMK kg^{-1}, which is higher than the price of maize 162 to 212 MMK kg^{-1} in 2015 (Global Agricultural Information Network [GAIN], 2018). The price of maize which was grown in dry season was higher than that of rainy season. If irrigation water is available, maize can grow during dry season even in central dry zone. However most farmers used furrow irrigation method. In addition, growing maize during dry season increased annual production (GAIN, 2018). The total production of maize is inadequate to meet the continuous increase of consumption. To raise maize production, there are necessities for the adequate supply of irrigation water, N, P, K fertilizers, high yielding cultivars, agronomical practices like optimum plant density, timing of different treatments and interventions etc. affecting directly the growth and productivity.

In recent years, irrigation water supplies are decreasing in many areas of the world. Due to the climate change, predictions of increase in temperature and decrease in rainfall, water will become increasingly scarce. Therefore, yield of maize can also be affected under drought condition because the root is relatively shallow and is always mainly concentrated in raised bed. Irrigation water is possibly infiltrated to somewhere deep under crop root zone to some extent while the topsoil is still dry. The water use efficiency under this condition is very low (Kang, Wang, & Liu, 2002).

Presently, many farmers are facing some irrigation water problems because irrigation water supplies are in shortage. Some researchers and farmers have been motivated by water shortage to find ways to produce maize with less irrigation water and changing from fully-irrigated to deficit irrigated cropping system. Saving more water will be helped by using modern irrigation systems and proper irrigation management which can be used to cultivate more land. Despite there are diverse lands such as dry land to grow maize in various region and state of Myanmar, available of water is a major constraint of grain yield. As irrigation restrictions increase it will be important to better understand the benefits of irrigation and the risks of maize production. Suitable water management practices will be needed to improve for maize to increase yield and meet maize grain demand. In order to maximize grain yield, water conserving management practices needs to pair with appropriate varieties for these practices and conditions. Better understanding the effects of irrigation and water availability on yield and yield components will be beneficial for making management decisions in the future (Brouwer, Prins, & Heibloem, 1989).

The total precipitation does not meet the water requirements of maize crop. The seasonal water requirements of maize vary from 600 - 700 mm depending on the total length of the growing period, planting time, cultivar, soil type and seasonal conditions (Reddy, 2006). The full potential yield of maize will only be attained when it is grown without stress throughout the season (O'Gara, 2007). Thus, it will be needed to apply water using effective irrigation methods. The different methods of irrigation contain terraced irrigation, sprinkler irrigation, drip irrigation, furrow irrigation, basin irrigation etc. (Usoh, Nwa, Okokon, Nta, & Etim, 2017).

Furrow irrigation is also suited to the growing of row crops such as maize, sunflower, sugarcane, soybean etc. In the early stages of maize planting, one furrow alongside the maize row may be sufficient but as the maize develop then two or more furrows can be constructed to provide sufficient water (Food and Agriculture Organization [FAO], 2011). Furrow irrigation method was mostly used, but it requires more labor for irrigation, both run-off and deep percolation losses are difficult to control. One of the ways of effective water management strategies is the use of drip irrigation system. Drip irrigation has been used for agricultural production for previously 35 years. Drip irrigation method has many advantages over traditional practices as surface irrigation due to reduced labour requirements and its ability to conform to irregularly shaped fields (Michael, 2008). It can also receive higher efficiencies than sprinkler or surface irrigation (Camp, 1998). This irrigation system is one of the methods which enables a lessening of water use and increase of water use efficiency. Therefore, the present study was undertaken with the following objectives:

Objectives

1. To compare the effects of drip irrigation and furrow irrigation method in maize production
2. To evaluate yield and agronomic characters of five maize varieties, and
3. To observe the interaction effect of irrigation methods and varieties on yield attributes and agronomic characters of maize

CHAPTER II
LITERATURE REVIEW

2.1 Importance of Maize

Maize is the third most important cereal crop after wheat and rice and is grown across a wide range of climates but mainly in the warmer temperate regions and humid subtropics in the world (Harris, Rashid, Miraj, Arif, & Shah, 2007). It is also one of the most important crops in the tropical and subtropical regions of the world. Generally, tropical maize is grown between 30˚N and 30˚S, subtropical maize between 30˚N and 34˚S, and temperate maize beyond 34˚ latitudes. Maize can be grown in a range of altitudes from sea level up to 3,800 meters (Prasai, Sharma, Kushwaha, & Shrestha, 2015) and in areas with 250 mm to more than 5000 mm of rainfall per year and with a growing cycle ranging from 3 to 13 months (Shaw, 1988).

Maize provides staple food to many population. It is the most important cereal crop in Sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (International Institute of Tropical Agriculture [IITA], 2012). Maize is not only an important human nutrient but also a basic element of animal feed and raw material for manufacture of many industrial products (Huang, Birch, & George, 2006). Maize seeds have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar and 1.7% ash (Chaudhary, 1983). It is an important source of carbohydrate, protein, iron, vitamin B, and minerals as well as a major source of starch. Over the past 40 years, the total global area sown to maize has increased by about 40% and production has doubled. In 2016 - 2017, the U.S was responsible for more than one-third of the global corn production.

2.2 Uses of Maize

The harvested part of maize is grain which is used for human and livestock consumption. All parts of this generally tall plant are utilized with the stalks for fodder and livestock feed as well as paper and wallboard, the cobs and kernels for food and fuel, the husks for tamales and the silk for medicinal tea. Maize is sometimes used as the starch source for beer.

The maize seed can be prepared for food in many different ways (fried, grilled, in a salad or soup). Processing maize can also produce a wide range of products such as maize flour and maize meal. Maize flour is a major ingredient in home cooking and in many industrialized food products. Maize meal is also used as a replacement for wheat flour, to make corn bread and other baked products. Maize serves as the foundation for such products such as bourbon, corn flour, corn oil, corn meal, corn starch, corn syrup, and laundry starch (Herbst & Herbst, 2007). Starch from maize can also be made into plastics, fabrics, adhesives, and many other chemical products. Maize is also a major source of cooking oil (corn oil) and of maize gluten. Maize silage is one of the most valuable forages for ruminants (Heuzé, Tran, Sauvant, & Lebas, 2017). In the USA, the price of maize (corn) doubled between 2006 and 2007 due to an increasing demand from the ethanol industry. Ethanol is a fuel which was made by maize. It is mixed with gasoline to decrease the amount of pollutants emitted when used to fuel motor vehicles (Tibaquirá, Huertas, Ospina, Quirama, & Niño, 2018).

2.3 Production of Maize

Generally, maize production in the world is dominated by relatively few countries, with the top five being USA, China, Brazil, Mexico and Argentina. These countries accounted for nearly 75% of the total world production (Nafziger, 2010). The world maize production is about 1008 million tons grain from approximately 177 million hectares of land (GEOFIN, 2016).

Myanmar is a maize producing and exporting country among 163 maize producing countries in the world. The main maize production areas in Myanmar are primarily found in the hilly and dry zones of the country with smaller production taking place in the delta and coastal regions. Maize is cultivated mainly in the country’s site of Shan, Chin states and Sagaing, Magway and Mandalay regions as a seasonal crop in monsoon and winter. Currently, in Myanmar, the crop is grown an area of 504,000 hectares with the production of 1940,000 MT bring an average production of more than 3.88 t ha^{-1} or 1.57 t ac^{-1} (MOALI, 2018). Maize production of Myanmar increased from 61,861 tonnes in 1968 to 1.94 million tonnes in 2017 growing at an average annual rate of 8.28% (MOALI, 2018).

Farmers primarily used high-yield hybrid seeds, which account for more than 85 percent of corn production. Hybrid corn seeds are provided by Thailand, China, and Vietnam based companies, such as CP, Seed Asia, Ayeyarwady, Seven Tiger, etc., mostly through contract farming (GAIN, 2018).

Maize production in Myanmar is expected to increase to 2.25 MMT in 2017 - 2018 and 2.3 MMT in 2018 - 2019 due to the expansion of both rain fed and winter corn growing areas, particularly in Shan State (eastern part of the country), and due to the replacement of pulse areas with corn in the delta and central dry zone. The main maize crop is sown during the rainy season from May - June and harvested in September - October, especially in the central dry zone and hilly regions. The dry - season maize crop is sown in November - December and harvested in February - March, mostly in the delta regions. About 90 percent of Myanmar's maize crop is grown in rain-fed areas. According to the governmental sources, about 52 percent of Myanmar's maize production area is placed in Shan State (eastern region of the country) in 2016 - 2017 (GAIN, 2018).

Maize is sown in northern Shan state and it is sent straight to the town of Muse on the Myanmar - China border, and then traded to Shweli in China. CP corn in Myingyan (Mandalay Region), Monywa (Sagaing Region), and Taunggyi (Shan State) is shipped to Mandalay, where it's bought by traders to sell to China. The price of dry season maize was higher than that of rainy season (Appendix 1).

Up to 2008, Myanmar has exported over 3,000,000 MT of maize annually to Malaysia and Bangladesh through oversea trade. Presently, 73 private companies have exported Myanmar maize mainly to China through border trade. Myanmar corn exports in 2017 - 2018 and 2018 - 2019 are forecast to increase 1.5 MMT in anticipation of robust trade with China. In 2017 - 2018, according to government and trade sources, almost 92 percent of Myanmar's maize exports took place along the border between Myanmar and China. The remaining eight percent was exported to Singapore, Malaysia, the Philippines, Vietnam, Taiwan and Hong Kong (GAIN, 2018).

2.4 Climatic and Soil Requirements for Maize Cultivation

Maize is generally a crop of warm climates with adequate moisture and annual crop. Maize grows within the temperature range 10°C - 40°C, the optimum temperature being around 30°C. Temperatures below 8°C or above approximately 40°C usually cause cessation of plant development (Birch, Robertson, Humphreys, & Hutchins, 2003). Rainfall is a limiting factor to dry land production of commercial maize crops and this affects the high or low yields obtained. Maize is particularly susceptible to water stress at flowering stage when yield is set.

Maize requires a good deal of sunshine and low levels of humidity, otherwise it is prone to disease and inadequate pollination (Mayhew & Penny, 1988). The most desirable soil for maize is generally considered to be a deep, medium textured soil, preferably high in organic matter, well-drained, high in water-holding capacity, and capable of delivering to the plant all of the essential nutrients in amounts needed by the growing crop (Pierre, Aldrich, & Martin, 1972). It can be grown successfully in soils whose pH ranges from 5.5 (rather acidic) to 8.0 (moderately basic). Sandy soils, unless heavily manure, are not desirable for maize, as they dry out quickly and are usually low in fertility. On the other hand, clay soils are, as a rule, poorly drained and too compact to produce the best maize (Wallace & Bressman, 1937).

Loamy soil is the best all-round type of soil for producing farm crops and is comparatively easy to work. This ability to work freely is due to a smaller portion of clay and a larger proportion of sand (Park & Eddowes, 1975). Maize is heavy feeder and quickly depletes soil nitrogen, phosphorus and potassium (Onasanya et al., 2009). It grown for whatever reason at commercial or small scale level has high demand for nutrients, especially nitrogen, phosphorus and potassium. Depending on the soil type, the micronutrients Zinc and Molybdenum are also important (Adhikary, Shrestha, & Baral, 2010).

2.5 Corn Plant Growth and Development Stages

Different growth stages are numbered 0 to 10 (Du Plessis, 2003).

Growth stage 0: from planting to seed emergence

During germination, the growth point and the entire stem are about 25 to 40 mm below the soil surface. Under warm, moist conditions seedlings emerge after about 6 to 10 days, but under cool or dry conditions this may take two weeks or longer. The optimum temperature range for germination is between 20 and 30ºC, while optimum moisture content of the soil should be approximately 60% of soil capacity.

Growth stage 1: four leaves completely unfolded

The growth point at this stage is still below the soil surface and aerial parts are limited to the leaf sheath and blades. Initiation of tasseling also occurs at this stage.

Growth stage 2: eight leaves completely unfolded

During this period, leaf area increases five to 10 times, while stem mass increases 50 to 100 times. Ear initiation has already commenced. Tillers begin to develop from nodes below the soil surface. The growing point at this stage is approximately 5,0 to 7,5 cm above the soil surface.

Growth stage 3: twelve leaves completely unfolded

The tassel in the growing point begins to develop rapidly. Lateral shoots bearing cobs develop rapidly from the sixth to eighth nodes above the soil surface and the potential number of seed buds of the ear has already been determined.

Growth stage 4: sixteen leaves completely unfolded

The stem lengthens rapidly and the tassel is almost fully developed. Silks begin to develop and lengthen from the base of the upper ear.

Growth stage 5: silk appearance and pollen shedding

All leaves are completely unfolded and the tassel has been visible for two to three days. The lateral shoot bearing the main ear as well as bracts has almost reached maturity. At this point demand for nutrients and water is high.

Growth stage 6: green mealie stage

The ear, lateral shoot and bracts are fully developed and starch begins to accumulate in the endosperm.

Growth stage 7: soft dough stage

Seeds mass continues to increase and sugars are converted into starch.

Growth stage 8: hard dough stage

Sugars in the seed disappear rapidly. Starch accumulates in the crown of the seed and extends downwards.

Growth stage 9: physiological maturity

When the seed has reached its maximum dry mass, a layer of black cells develop at the kernel base. Seeds are physiologically mature and only the moisture content must be reduced.

Growth stage 10: drying of kernels (biological maturity)

Although seeds have reached physiological maturity, they must dry out before 10 reaching biological maturity. Under favorable conditions, drying takes place at approximately 5% per week up to the 20% level, after which there is a slowdown.

The development staging system most commonly used is the Iowa System. It divides plant development into vegetative (V) and reproductive (R) stages. V stages are designated numerically as Emergence (VE), First leaf (V1), Second leaf (V2), Third leaf

(V3),…,Vn, where n represents the last stage before VT (tasseling). R stages are designated numerically as R1 Silking, R2 Blister, Milk (R3), Dough (R4), Dent (R5) and Physiological maturity (R6) (Du Plessis, 2003).

2.6 Irrigation

Irrigation is defined as the application of water to soil for any number of the purposes of supplying the moisture essential for plant growth or to provide crop insurance against short duration drought, to cool the soil temperature, to wash out or dilute salts in the soil, to reduce the hazard of soil piping, and to soften tillage pans (Hansen, Israelsen, & Stringham, 1980). This technique involves artificially providing crops with water to enable them to grow consistently and it is also used in farming to enable plants to grow when there is not enough rain, particularly in arid areas. Furthermore, irrigation is very important to provide plants when seed setting in less arid regions.

In 1800, the total worldwide irrigated land area was about 8 million hectares. This has been increased five-fold during the 19th century because of various scientific and technical foundation for irrigation was developed tremendously (Allen, Wright, Pruitt, Pereira, & Jensen, 2007). In 2012, over 324 million hectares are supplied for irrigation, of which about 85 percent or 275 million hectares are actually irrigated cropland (FAO, 2016). Currently, India and China has nearly the same amount of irrigated land area (69.4 and 66.7 million hectares of worldwide irrigated land area, respectively) (FAO, 2016). It is estimated that about 36% to 47% of the world’s food is produced by irrigated production (Postel, 1999; Gleick, 1998). In developing countries, irrigation is one of the largest investment in the agricultural and rural sector (World Bank, 2003). During the periods of the 1970s and 1980s, the peak of irrigation implementation, 50% of the irrigation investment was in agriculture. Thus, irrigation is very important in the agricultural sector.

National Agro-Technical Extension Service Centre (2003) stated that unreasonable irrigation will lead to a low yield although input is high. While reasonable irrigation gives the crop a proper water supply, which will not only satisfy the need for normal growth but also avoid water losses. Effective irrigation will be encouraged the full growth and yield process from seedbed preparation, germination, root growth, nutrient utilization, and plant growth and regrowth, and yield and quality (Akinyele, Oladimeji, Anjorin, Akinola, & Oke, 2016). Among several crops, maize takes approximately 100 to 120 days to reach physiological maturity depending on variety and will usually require about 100 days of irrigation. The full potential yield of maize will only be achieved when it is grown without stress throughout the growing season (O'Gara, 2007). Caswell (1991) reported that irrigated corn yields were about 29 percent higher than non-irrigated corn yields.

2.7 Effect of Irrigation on Maize Production

Irrigation will be increasingly important in certain parts of the country to ensure intensive production of maize (Molnár, 1977). The effect of irrigation changed depending on the natural water supply and nutrient supply of soil, and the specific fertilizer doses. The seasonal water requirements of maize vary from 600 - 700 mm depending on the total length of the growing period, planting time, cultivar, soil type and seasonal conditions (Reddy, 2006). The production of maize can be improved positively by sufficient amount of irrigation (Kara & Biber, 2008; Yazar, Howell, Dusek, & Copeland, 1999). Maize yields are most sensitive to water stress, especially at flowering and pollination stages (El-Hendawy, Hokam, & Schmidhalter, 2008).

Effects of water stress on maize include the visible symptoms of reduced growth, delayed maturity, and reduced crop yield. Water stress during maize growing season resulted in decreasing of plant height, reduction in leaf area index and in total leaf area (El-Shenawy, 1990; Cassel, Martin, & Lambert, 1985). Cakir (2004) observed that water stress occurring during reproductive stages reduced plant height and delayed silking, as well as leaf area development. Severe water stress during silking can cause to desiccate the silks and pollen grains causing poor pollination. Claasen and Shaw (1970) also found that water stress before silking and pollination stage resulted in reduced grains number, while stress after silking and pollination stage reduced grains weight. In addition, number of ovules that fertilized and developed into grains decreased rapidly when drought occurred during flowering (Gomma, 1981). Moreover, both final maize yield and grains number were reduced as a result of water stress during grain filling period (Ritchie, Hanway, & Benson, 1993). Water stress can affect growth, development, and physiological processes of corn plants, which can reduce biomass and grain yield due to a reduction in the number of grains ear^{-1} or the grain weight (Traore, Carlson, Pilcher, & Rice, 2000; Denmead & Shaw, 1960). Water stress conditions may cause 22.61 - 26.4% yield reduction which is directly correlated with the decrease in grains number and grains weight (Pandey, Ved, Mani, & Singh, 2000).

Deficit irrigation creates water stress that can affect the growth and development of corn plants. It is very important to estimate yield reduction due to applying deficit irrigation strategies (Payero, Melvin, Irmak, & Tarkalson, 2006). Water deficit affects timing of emergence, reduces number of leaves plant^{-1} but delays tasseling initiation and silking, reduces plant height and vegetation growth of maize (Abrecht & Carberry, 1993; Singh, Roy, & Kaur, 2007). The heading to milking growth stage is highly sensitive period of deficit irrigation and has ultimate effect on productivity of maize (Hussaini, Ogunlela, Ramalan, & Falaki, 2008). They found that grain yield can be reduced by decreasing yield components like ear size, number of grains ear^{-1}, or the grain weight. Pandey, Maranville and Admou (2000) reported that yield reduction (22.6 - 26.4%) caused by deficit irrigation was associated with a decrease in number of grains ear^{-1} and ear weight. Water deficit during differentiation and beginning of ear growth reduced the grain yield from 23 to 34% due to the decrease of the number of grains ear^{-1} from 15 to 26%.

2.8 Irrigation Scheduling

Irrigation scheduling is the technique to timely and accurately give water to a crop. Irrigation scheduling as a planning and decision-making activity that the producer of an irrigated farm is involved in before and during the growing season (Jensen, Rangeley, & Dieleman, 1990). The decision must be based on the available irrigation water supply, the soil water holding capacity and water intake rate, and the corn water needs. How much water to apply depends on (1) the soil's available moisture storage capacity and (2) the amount of available water depleted from the soil profile by crop water use. Rhoads and Yonts (2000) stated that to start an irrigation event depends on crop water use and plant available water in the soil profile.

Irrigation scheduling has been described as the primary tool to improve water use efficiency, increase crop yields and increase the availability of water resources (FAO, 1996). Irrigation scheduling requires knowledge on several factors: crop water necessities and yield responses to water, conditions and limitations of the irrigation system, the water supply availability, and expected economic return (Pereira, Feddes, Gilley, & Lesaffre, 2013). Well-timed irrigations provide enough water to prevent maize stress while fully using water from rainfall and available in the soil. Therefore, irrigation scheduling accounts for all plant sources of water to produce economic yields.

The purpose of irrigation scheduling is to determine the exact amount of water to apply to a field and then the exact timing for application, to apply enough water to fully wet the plant's root zone while minimizing over watering and then allow the soil to dry out during watering, to allow air to enter the soil and encourage root development, but not so much that the plant is stressed beyond what is allowable. Irrigation scheduling offers several advantages, it enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields. Irrigation scheduling reduces the farmer's cost of water and labour through less irrigation, thereby making maximum use of soil moisture storage (Igbadun, Mahoo, Tarimo, & Salim, 2005).

2.9 Effect of Irrigation Scheduling on Maize Production

Timing and supplemental irrigation is important in irrigation scheduling for the most effective use of available water in optimizing maize production. Maize water use rates decline at the beginning of the dough stage in response to lower atmospheric demand (shorter days and cooler temperatures and lower solar radiation), loss of transpiring leaf area, and changes in plant physiology as the grain approaches maturity. Limited water supply during the growing season results in soil and plant water deficits, causing a decrease in maize yields (Gordon, Raney, & Stone, 1995; Patel, Patel, & Patel, 2006).

Khan, Hussain and Iqbal (2001) studied the effect of water stress on growth and yield of maize. The study comprised of six treatments viz., control (Six irrigations), five, four, three, two and one irrigation only. It was found that number of grains ear^{-1}, thousand grains weight and grain yield have been decreased by increasing water stress. Maximum grain yield (3500 kg ha^{-1}) was obtained in six irrigations and minimum grain yield (400 kg ha^{-1}) was achieved by applying one irrigation. Dogan and Kirnak (2010) stated that the highest number of grains ear^{-1} of maize were obtained from six time irrigation and the lowest values were gained from four time irrigation.

Khan, Asif and Aman (2003) observed that different irrigation levels were significantly affected the grain yield. The application of six times irrigation produced significantly the maximum grain yield (6500 kg ha^{-1}) and thousand grains weight (275.2 g) while the minimum grain yield (2200 kg ha^{-1}) and thousand grains weight (153.9 g) was obtained in four times irrigation.

Filintas, Dioudis, Hatzopoulos and Karantounias (2008) observed that 9 days interval irrigation gave the highest yield (13800 kg ha^{-1}). The lowest yield was gained in 12 and 15 days interval (12100 and 10300 kg ha^{-1}). The irrigation interval was negatively affected the yield in 12 and 15 days interval caused higher values of soil moisture depletion, which led plants periodically to water stresses.

Prolonging watering intervals reduced the number of grains ear^{-1}; this reduction under water stress have been reported by many researcher and was attributed to delayed silking (Westgate & Boyer 1986) and reduced pollen viability (Hall, Vilella, Trapani, & Chimenti, 1982). Yang and Hsiang (1994); Ahmed and El Hag (1999); Ahmed (2002) observed that prolonging watering intervals decreased plant grain yield and grain yield per hectare.

2.10 Systems of Irrigation

There are many systems in irrigation. Irrigation is an artificial application of water supply to the soil usually for assisting in growing of crops. The systems of irrigation are surface irrigation, subterranean irrigation (subsurface irrigation), sprinkler irrigation and drip irrigation, etc. (Usoh, Nwa, Okokon, Nta, & Etim, 2017).

2.10.1 Surface Irrigation

Surface irrigation is the oldest and most common method of applying water to croplands. The water moves over and across the land through simple gravity flow in order to wet and to infiltrate into the soil. Surface irrigation methods are the best suited to soils with low to moderate infiltration capacities and to lands with relatively uniform terrain with slopes less than 2 - 3% (FAO, 1984).

Surface irrigation is often referred to as flood irrigation, implying that the water distribution is uncontrolled and therefore, inherently inefficient. Flood irrigation on red soils results in erratic wetting and poor water distribution, causing unsustainable water loss due to deep drainage through the profile. Surface irrigation can be subdivided into basin irrigation, border strip irrigation and furrow irrigation (Bamohuni, 2011).

The first ones of surface irrigation is basin irrigation, it is horizontal, flat plots of land, surrounded by small dykes or low bunds. The bunds prevent the water flowing to the adjacent fields. Basin irrigation is an effective method of leaching salts from the soil profile. Basin irrigation is favoured in soils with relatively low infiltration rates (Walker & Skogerboe, 1987). Basin irrigation is usually used for rice production on flat lands or in terraces on hillsides. Trees (e.g. citrus and banana) can also be grown in basins, where one tree usually is located in the middle of a small basin. The second of the surface irrigation is border strip irrigation, border strip width depends on the topography of the field, which determines the possible width that can be obtained while keeping a horizontal cross-section without requiring too much soil movement, and on the stream size. The stream size also restricts strip width, as it should be sufficient to allow complete lateral spreading throughout the border strip width and length. Water is applied to individual borders from the field head ditch and utilizes the elevation differences to traverse the field. When the water is shut off, it recedes from the upper end to the lower end. The water is released from the field ditch into the border through gate structures called outlets. The sheet of flowing water moves down the slope of the border, guided by the border ridges. The last of the surface irrigation is furrow irrigation, it is narrow ditches dug on the field between the rows of crops. The water runs along them as it moves down the slope of the field. The water flows from the field ditch into the furrows by opening up the bank or dyke of the ditch or by means of siphons. Furrow irrigation is particularly suited to broad-acre for row crops such as cereals (maize), horticultural industries such as citrus, and vegetables (onions, tomatoes, eggplant, okra, etc).

Furrows provide better on-farm water management capabilities under most surface irrigation conditions. Flow rates per unit width can be substantially reduced and topographical conditions can be more severe and variable. A smaller wetted area can reduce evaporative losses on widely spaced crops. Furrows provide operational flexibility important for achieving high efficiencies for each irrigation throughout a season. It is a simple (although labor intensive) matter to adjust the furrow stream size to changing intake characteristics by simply changing the number of simultaneously supplied furrows (Walker, 2003). Among the surface irrigation methods, furrow irrigation technique is known to have better efficiency and can be used in situations where water shortage is critical. In Ethiopia, 97.8% of irrigation is made by surface methods of irrigation especially by furrow system in farmer’s fields and majority of the commercial farms (FAO, 2001).

2.10.1.1 Advantages of Furrow Irrigation

Advantages of furrow irrigation reduces initial investment of equipment and pumping costs per acre-inch of water pumped. Furrow irrigation practice can minimize irrigation costs and chemical leaching and result in higher crop yields.

2.10.1.2 Disadvantages of Furrow Irrigation

Disadvantages of furrow irrigation requires more labor than border and basin irrigation and are occasionally more difficult to automate (Namara, Upadhyay, & Nagar, 2005). This method needs to level and remove any small hills that would have been bypassed by the gravity flow of the water because difficulties of furrow irrigation is ensuring uniform dispersion of water over a given field.

2.10.2 Subterranean Irrigation System (subsurface irrigation)

Subsurface irrigation is the practice of applying water to soils directly under the surface. Moisture reaches the plant roots through capillary action. When soil conditions are favorable for the production of cash crops on small areas, a pipe distribution system is placed in the soil well below the surface. Subsurface irrigation is a low-pressure, high efficiency irrigation system that uses buried drip tubes or drip tape to meet crop water needs. Subsurface irrigation saves water and improves yields by eliminating surface water evaporation and reducing the incidence of weeds and disease. Soils which permit free lateral movement of water, rapid capillary movement in the root zone soil, and very slow downward movement of water in the subsoil are very suitable for artificial subirrigation. When managed properly with a fertilizer injector, water and fertilizer application efficiencies are enhanced, and labor needs are reduced (Boutheina & Boujelben, 2011).

2.10.3 Sprinkler Irrigation System

Sprinkler irrigation system conveys water from the source through pipes under presser to the field and distributes over the field in the form of spray of rain like droplets. It is also known as overhead irrigation. It is used for irrigating gardens concessions. But it is especially used in large areas for crop production. The national society of sugar production also uses this technique for the production of sugarcane (Bamohuni, 2011).

A sprinkler irrigation system generally includes sprinklers, laterals, sub mains, main pipelines, pumping plants and boosters, operational control equipment and other accessories required for efficient water application.

2.10.4 Drip Irrigation System

According to (FAO, 1984), drip irrigation was first used in glass houses in England in the late 1940s and in open fields in Israel in the 1950s. In 2010, 40% of irrigated land in California utilized drip irrigation system (Ayars, Fulton, & Taylor, 2015). India now leads in the world, with nearly 2 million hectares (about 5 million acres) applied drip irrigation methods.

Drip irrigation is also known as trickle or micro irrigation in which water delivered at or near the root zone of plants in drop by drop. In drip irrigation, the water is led to the field through a pipe system. It is most suitable for row crops (vegetables, soft fruit), tree and vine crops where one or more emitters can be provided for each plant. Drip irrigation is suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.

Drip irrigation method can be more efficient with proper management of the system by minimizing evaporation and runoff losses. The field water efficiency of drip irrigation is typically in the range of 80 to 90 percent when managed correctly. Namara, Upadhyay and Nagar (2005) on the effects of drip irrigation revealed that it is a means of saving water in irrigated agriculture, which reduce run off, decreasing percolation of water beneath the root zone and reduce water evaporation after irrigation.

Drip irrigation shows its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of the root zone. The benefits of drip irrigation may include better crop survival, minimal yield variability and improved crop quality. Yildirim and Korukcu (2000) stated that drip irrigation mostly gains better crop yield and balanced soil moisture in the active root zone with minimum water losses. Darouich, Pedras, Gonçalves and Pereira (2014) found that drip irrigation saves about 28 - 35% water as compared to conventional surface irrigation methods. After more than 20 years of research, trials and field used worldwide, drip irrigation systems have proven to be the most efficient means of water distribution and application and an ideal way of supplying the plants with nutrients. The objectives of drip irrigation are: bring water and locally in the root zone, ensure the supply in a high frequency and low-flow supplying to permit a low variation of moisture.

2.10.4.1 Advantages of Drip Irrigation

The higher degree of inbuilt management that drip irrigation offers reduces substantially deep percolation and runoff losses, thus achieving higher irrigation efficiencies. Consequently, drip irrigation is considered as a water-saving technology. Its major advantages as compared to other methods include: higher crop yields, saving in water, increased fertilizer use efficiency, reduced energy consumption, tolerance to windy atmospheric conditions, reduced labor cost, improved diseased and pest control, feasible for undulating sloppy lands, suitability on problem soils and improved tolerance to salinity (Michael, 2008). The moisture availability to the plant at low tension results in faster growth, higher yield and better quality. Fertilizer and nutrient loss is minimized due to a localized application and reduced leaching. Water distribution is highly uniform, controlled by the output of each nozzle. Labour cost is less than other irrigation methods.

2.10.4.2 Disadvantages of Drip Irrigation

Initial investment costs may be higher than those of other irrigation system. If the water is not properly filtered and equipment not properly maintained, it can result in clogging. Drip systems are prone clogging because of the very small aperture of the water emitting devices. The movement of the salts to the fringes of wetted area of the soil may cause salinity problems through the leaching of the salts by the rain to main root volume. This can be avoid if the system is turned on when it rains, especially when the amount of rain is not enough to leach the salt beyond the root zone depth. Rodent, dogs, insect, and human damage to drip lines are potential sources of leaks (Bamohuni, 2011).

2.11 Effect of Drip Irrigation on Maize Production

Drip irrigation is one of the most efficient methods of irrigation in terms of application efficiency and reducing soil evaporative losses (Irmak, Djaman, & Rudnick, 2016). Yazar, Sezen and Gencel (2002) studied the effects of three different irrigation levels (314mm, 450mm, 581mm), and two irrigation intervals (three and six days) with drip irrigation on maize yield. A total of 581 mm of water was applied to the full-irrigation treatments (100%) for both irrigation intervals. It was found that highest grain yield (11920 kg ha^{-1}) was gained from the full-irrigation treatment (100%) with six-day interval and followed by (11330 kg ha^{-1}) was received from the full-irrigation treatment (100%) with three days interval under drip irrigation. Degirmenci, Gunduz and Kara (1998) laid out research during 1995 - 1997, using furrow irrigation, and they achieved an average grain yield of 9260 kg ha^{-1} and seasonal water use of 938 mm, and applied 873 mm of irrigation water. Hence, if these values are compared with the findings from this experiment, then drip irrigation could save water by as much as 55% compared to furrow irrigation, while a grain yield increase of 15 - 23% would be possible.

Ibragimov et al. (2007) reported that 18 - 42% saving of irrigation water and 35 - 103% increase in irrigation water use efficiency (IWUE) with drip irrigation compared to furrow irrigation in maize crop. Maximization of crop yield, quality and minimization of leaching loss of nutrients could be achieved by using drip irrigation (Yaghi, Arslan, & Naoum, 2013). El-Wahed and Ali (2013) showed that the drip irrigation system maximized maize grain yield and water use efficiency compared to the sprinkler irrigation system.

This is clearly suggesting that increased frequency for drip irrigation is beneficial in respect of water saving, nutrient and water uptake, plant dry matter weight, grain yield and above all larger water use efficiency. This establishes that shortest interval of drip irrigation provides the best plant development and finally the yield of crop. Phene and Beale (1976) reported 12 - 14% more corn yields in drip plots than did the furrow and sprinkler irrigated plots. A short irrigation interval has been beneficial in drip irrigations system as it suppresses salt effects by avoiding concentration impact of salt on crop growth. Yazar, Sezen and Gencel (2012) stated that the maximum total grains per ear was achieved from full irrigation using drip irrigation method. Increasing available soil moisture during vegetative and reproductive growth of maize increased maize grain yield and its components (Khedr, Matta, Wahba, & El-Koliey, 1996; Ashoub, Hassanein, Abd-El-Aziz, Shahin, & Gohar, 1996).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The experiments were conducted in the Field of the Department of Agronomy, Yezin Agricultural University, Yezin, which is located at 19˚ 49' 59.6" N latitude and 96˚ 16' 30.4" E longitude with the elevation of 129 meters (423 feet) above sea level. The experiments were conducted during November to April in 2017 - 2018 and 2018 - 2019.

3.2 Experimental Design and Treatments

The field experiment was laid out in Split Plot Design with three replications, in which two levels of irrigation method (drip irrigation and furrow irrigation) were applied in main plot and five varieties (SA - 282, NK - 621, NK - 625, LG -778 and P - 515) were applied in sub plot. The whole size of the experimental area was 45 m x 30 m. The subplot size was 5 m × 5 m. Row spacing and plant spacing were 75 and 25 cm.

3.3 Soil Sampling and Analysis

Soil samples were analyzed to adjust fertilizer application. Soil samples were taken from 5 random samples on the surface of 15 cm depth from the experimental site with the help of auger and analyzed for available N, P, K, soil texture, pH and bulk density before sowing of crop. The soil sample was analyzed before and after the experimental set-up at Soil and Water Utilization Division, Department of Agriculture, Taunggyi. The physicochemical properties of experimental soil for 2017 - 2018 and 2018 - 2019 were presented in Appendix 2.

3.4 Crop Management

Firstly, land preparation was done using tractor by two times of ploughing and two times of harrowing. Sowing was done at the seeding rate of two seeds per hole. Weed was controlled using pre emergence herbicides. Thinning was done at 2 weeks after sowing and left one healthy seedling per hole. The infestation of weeds, pests and diseases were managed whenever it is necessary. Fertilizer was applied as SAPA Guideline as shown in Appendix 3. All treatment plots received the same amount of total fertilizer. For drip irrigation method, the total amount of 700 mm ha^{-1} of water required for the crop were applied at four days interval throughout the whole season (Appendix 4). For the furrow irrigation method, the same amount of water as in drip irrigation was used for the whole season at 25 days interval (Appendix 5). Total amount of water (700 mm ha^{-1}) was used for both drip and furrow irrigation but the amount of water was adjusted depending on rainfall if there was some unoccasional rain (Appendix 6 and Appendix 7).

3.5 Data Collection

The measured parameters and calculated parameters in this study were plant height (cm), ear height (cm), days to 50% tasseling (days), days to 50% silking (days), ear diameter (cm), ear length (cm), row length (cm), ear weight (g), number of grains ear^{-1}, number of rows ear^{-1}, number of grains row^{-1}, thousand grains weight (g), shelling %, number of ear $plant^{-1}$, grain yield (kg ha^{-1}), water productivity (kg m^{-3}) and harvest index.

Plant heights were recorded from five sample plants at two weeks interval. Ear heights were recorded from five sample plants at harvest. At harvest, yield and yield components such as ear diameter (cm), ear length (cm), row length (cm), ear weight (g), number of grains ear^{-1}, number of rows ear^{-1}, number of grains row^{-1}, thousand grains weight (g), shelling % and number of ear $plant^{-1}$ were recorded from randomly selected five sample plants of each plot.

The total grain yield (at adjusted 15 % moisture content) from each plot were weighed and converted to kg ha^{-1}.

$$\text{Seed yield}\left(\text{kg ha}^{-1}\right) = (100 - \text{moisture})\frac{(\text{field weight (kg) x shelling\% x 10000 m}^2)}{85 \text{ x harvested area (m}^2)}$$

(Centro International De Mejoramiento De Maiz Y Trigo [CIMMYT], 1985)

Where,

kg ha^{-1} = seed yield converted into kg per hectare

85 = adjusted factor of seed moisture to 15 %

10,000 sq meter = conversion factor to an area of one hectare of a plot

Shelling % was calculated from seed dry weight adjusted at 15 % moisture and ear dry weight as follow;

$$\text{Shelling \%} = \frac{\text{seed dry weight}}{\text{ear dry weight}} \text{x100}$$

(CIMMYT, 1985)

Water productivity was calculated by the following formula;

$$\text{Water productivity (kg m}^{-3}\text{)} = \frac{\text{grain yield (kg ha}^{-1}\text{)}}{\text{total water input (irrigation+rainfall) (m}^{3}\text{ ha}^{-1}\text{)}}$$

(Cook, Gichuki, & Turral, 2006)

Harvest index was calculated by the following formula;

$$\text{Harvest index (HI)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Total dry matter (kg ha}^{-1}\text{)}}$$

(Donald, 1962)

3.6 Data Analysis

The data were subjected to analysis of variances by using Statistix (8th version) software and treatment means were compared by using Least Significant Difference (LSD) test at 5% level of significance (Gomez & Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Experiment During November, 2017 to April, 2018

4.1.1 Yield and yield components

4.1.1.1 Number of grains row^{-1}

Although there were no significant difference in number of grains row^{-1} between two irrigation methods, relatively higher number of grains row^{-1} (32.00) was achieved in drip irrigation and the lower number (26.37) was gained in furrow irrigation (Table 4.1). The number of grains row^{-1} under furrow irrigation were reduced because of the 25 days interval of furrow irrigation in which the plants may be subjected to short term water deficit at certain growth stages although irrigation was applied. It may cause decreased grains number row^{-1}. McPherson and Boyer (1977); Hall, Lemcoff, and Trapani (1971) reported that the main reason of grain number decrease was the decrease of ear thick as a result of dry stress. The maximum number of grains row^{-1} were obtained from NK - 621 (31.08) followed by P - 515 (30.36), although they were not significantly different from other varieties. The lowest number of grains row^{-1} was obtained from NK - 625 (27.70).

4.1.1.2 Number of rows ear^{-1}

The number of rows ear^{-1} were not significantly affected by two irrigation methods and five tested varieties (Table 4.1). However, the maximum number of rows ear^{-1} was obtained from the variety NK - 625 (14.20) and the minimum number of rows ear^{-1} was gained from the variety LG - 778 (13.26). Although there was no significant interaction between irrigation methods and varieties in the number of rows (Table 4.1), the maximum number of rows ear^{-1} (14.4) was obtained from the variety NK - 625 under furrow irrigation and the minimum number of rows ear^{-1} (13.20) was achieved from the variety P - 515 under furrow irrigation (Figure 4.1).

4.1.1.3 Row length

Row length of maize was not significantly different between different irrigation methods and among the tested varieties (Table 4.1). The longer row length (15.81 cm) was achieved in drip irrigation and the shorter row length (13.30 cm) was gained in furrow irrigation (Table 4.1). Among all the varieties, the longest row length (15.43 cm) was obtained from NK - 621, followed by P - 515 (15.32 cm), while the shortest row length (13.38 cm) was obtained from SA - 282. Among all the treatments, the longest row length was obtained by drip irrigation in the variety P - 515 (17.95 cm) followed by the variety NK - 621 (16.66 cm) although they were not significantly different from each other (Figure 4.2).

Table 4.1 Mean values of yield and yield components of maize as affected by two irrigation methods and five tested varieties in the dry season (November, 2017 to April, 2018)

Treatments	No. of grains row^{-1}	No. of rows ear^{-1}	Row length (cm)	No. of grains ear^{-1}	Thousand grains weight (g)	Ear length (cm)	Ear diameter (cm)	Ear weight (g)	No. of ear $plant^{-1}$	Shelling %	Yield (kg ha^{-1})
A. Irrigation (I)											
Drip	32.00	13.78	15.81	441.25	257.42	17.38 a	4.27	182.41	1.01	82.33	5759.60
Furrow	26.37	13.70	13.30	365.11	242.92	14.85 b	3.96	136.77	1.00	82.06	4218.60
$LSD_{0.05}$	10.72	1.89	2.70	171.55	52.07	2.52	0.48	71.17	0.05	5.9	1789.10
B. Varieties (V)											
SA - 282	28.93	13.86 ab	13.38	402.33	214.33 c	15.03	3.91	134.60	1.03	81.73	4488.20 ab
NK - 621	31.08	13.86 ab	15.43	433.05	284.22 a	17.81	4.24	185.53	1.00	81.90	6548.30 a
NK - 625	27.70	14.20 a	14.34	393.12	269.16 ab	15.62	4.32	166.46	1.00	83.67	4851.80 ab
LG - 778	27.85	13.26 b	14.32	370.72	228.28 bc	15.49	3.93	141.43	1.00	81.27	3389.60 b
P - 515	30.36	13.53 ab	15.32	416.69	254.88 abc	16.63	4.19	169.94	1.00	82.39	5667.40 a
$LSD_{0.05}$	6.80	0.77	2.85	102.08	43.85	2.65	0.44	58.18	0.04	4.54	2164.10
Pr>F											
I	0.152	0.872	0.057	0.196	0.353	0.049	0.107	0.110	0.423	0.861	0.066
V	0.778	0.160	0.551	0.749	0.022	0.300	0.237	0.356	0.436	0.829	0.065
I*V	0.289	0.498	0.271	0.282	0.186	0.299	0.395	0.135	0.436	0.654	0.088
CV% (A)	23.39	8.78	11.83	27.08	13.25	9.96	7.44	28.39	3.63	4.62	22.82
CV% (B)	19.06	4.62	16.00	20.69	14.32	14.61	8.85	29.79	3.63	4.52	35.44

Mean values in each column having the same letter are not significantly different at 5% level
CV=Coefficient of variation

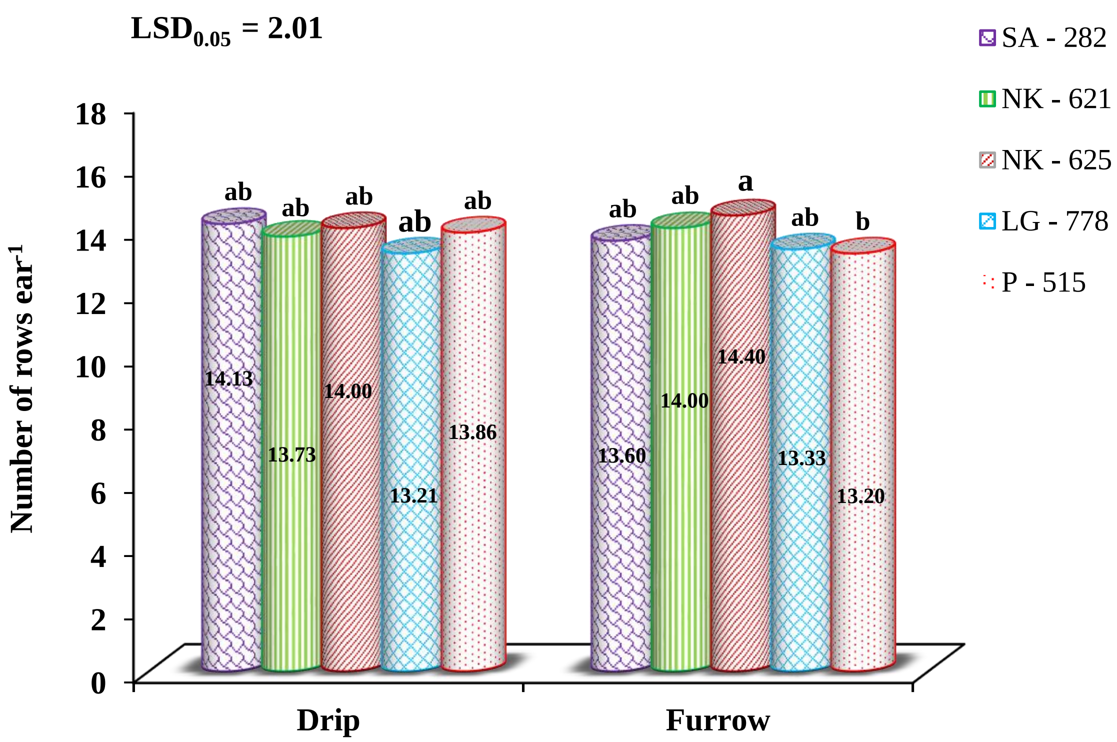


Figure 4.1 Number of rows ear^{-1} of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

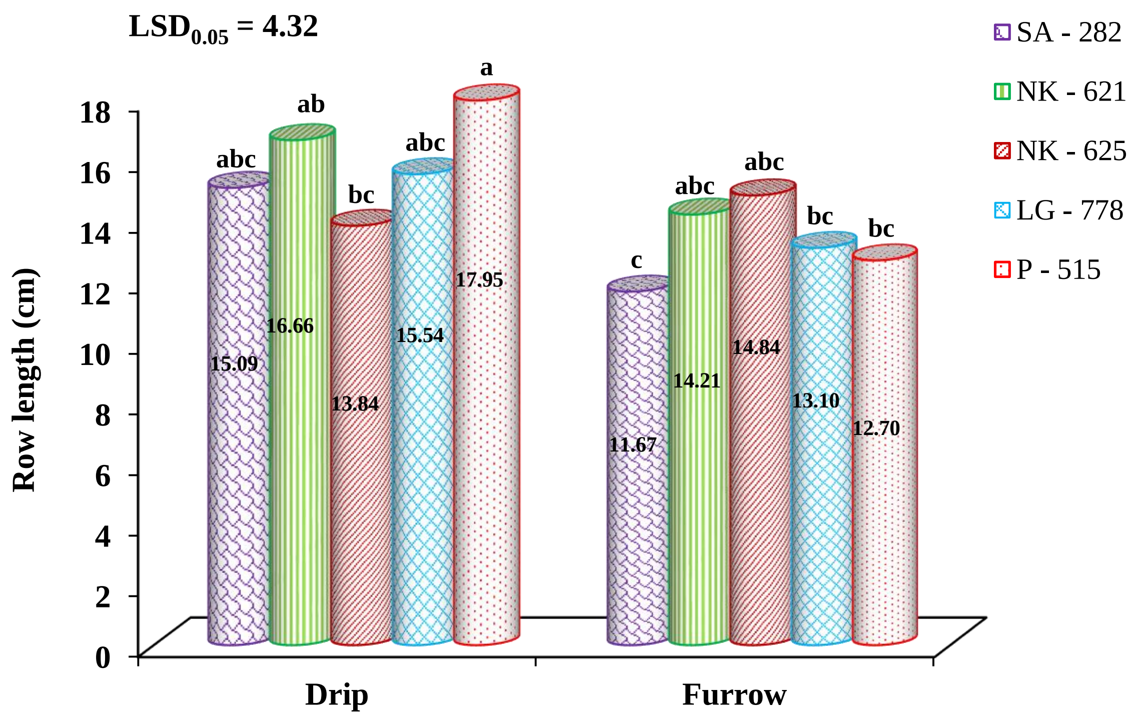


Figure 4.2 Row length of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

4.1.1.4 Number of grains ear^{-1}

In this study, number of grains ear^{-1} plays an important role to determine grain yield. The greater number of grains ear^{-1} (441.25) was recorded under drip irrigation although it was not significantly different from that under furrow irrigation (365.11) (Table 4.1). The plant grown by furrow irrigation may suffer short term water deficit at around reproductive stage. It may reduce the number of grains ear^{-1} and final yield production. Water stress during pollination of maize causes a small number of eggs fertilizing, or even it is possible not to fertilize at all, it also can cause abortion, accordingly fewer number of maize grain is produced (Bänziger, Edmeades, & Lafitte, 1999; Pervez, Srinivasan, Cordova, & Sanchez, 2004). Water stress during or before pollination reduces the number of grains, while water stress after pollination reduces grain weight (Bänziger, Edmeades, & Lafitte, 2002).

Mean comparison for varieties indicated that the maximum number of grains ear^{-1} (433.05) was obtained from the variety NK - 621, and the minimum number of grains ear^{-1} (370.72) was resulted from LG - 778 although there were no significant difference among the tested varieties (Table 4.1).

Although there was no significant interaction between irrigation methods and tested varieties in the number of grains ear^{-1} (Table 4.1).

4.1.1.5 Thousand grains weight

Although thousand grains weight was not significantly different between irrigation methods, significant differences among the varieties were observed by the maximum thousand grains weight (284.22 g) from the variety NK - 621, followed by NK - 625 (269.16 g) and P - 515 (254.88 g) respectively, whereas the minimum thousand grains weight (192.13 g) was attained from SA - 282 (Table 4.1). There was no significant interaction between irrigation methods and varieties in thousand grains weight.

4.1.1.6 Ear length

Significant difference in ear length was resulted by irrigation methods, but not by the varieties (Table 4.1). The longer ear length (17.38 cm) was recorded in drip irrigation and the shorter ear length (14.85 cm) was obtained in furrow irrigation (Table 4.1). The variety NK - 621 produced the longest ear length (17.81 cm) and the variety SA - 282 gave the shortest ear length (15.03 cm). Despite no significant response of maize varieties to irrigation methods in terms of ear length, the maximum ear length was obtained from the variety P - 515 (19.14 cm), followed by NK - 621 (18.62 cm) and SA - 282 (17.20 cm) under drip irrigation and the minimum ear length was found in the variety SA - 282 (12.87 cm) under furrow irrigation (Figure 4.3).

4.1.1.7 Ear diameter

The mean value of maize ear diameter was not significantly different between irrigation methods and among the five tested varieties (Table 4.1). However the greater ear diameter (4.27 cm) was noticed in drip irrigation and the thickest ear diameter (4.32 cm and 4.24 cm) were observed from the varieties NK - 625 and NK - 621 respectively, among the varieties. Although there was no significant interaction effect of irrigation methods and tested varieties on ear diameter (Table 4.1), the maximum ear diameter was obtained from the varieties P - 515 (4.51 cm), NK - 621 (4.43 cm) under drip irrigation and NK - 625 (4.43 cm) with furrow irrigation (Figure 4.4).

4.1.1.8 Ear weight

No significant differences in ear weight were observed between irrigation methods and among the different varieties. However, relatively greater ear weight (182.41 g) was resulted in drip irrigation while relatively lower weight (136.77 g) was found in furrow irrigation (Table 4.1). Among the varieties, NK - 621 gave the highest ear weight (185.53 g) and SA - 282 gave the lowest ear weight (134.60 g) (Table 4.1). According to the results, the response of varieties to irrigation methods were not significantly different (Table 4.1). Nevertheless, the maximum ear weight was achieved from the variety P - 515 (220.7 g) and NK - 621 (212.0 g) under drip irrigation and the minimum ear weight (93.6 g) was gained by the variety SA - 282 under furrow irrigation (Figure 4.5).

4.1.1.9 Number of ear plant^{-1}

Number of ear plant^{-1} was not significantly different between irrigation methods and among the varieties (Table 4.1). The average one ear plant^{-1} was resulted by all varieties under both irrigation methods. However, the variety SA - 282 tended to give more number of ear plant^{-1} (1.03) than the other varieties (1.00). In this season, there was no significant interaction between irrigation methods and tested varieties in the number of ear plant^{-1} (Table 4.1).

4.1.1.10 Shelling percentage

Shelling percent of maize was not significantly different between irrigation methods, varieties, and among all the treatments as well (Table 4.1 and Figure 4.6). However, among all the treatments, the highest shelling percentage was gained by furrow irrigation in variety SA - 282 (83.89%) and the lowest shelling percentage was obtained in the variety SA - 282 (79.58%) under drip irrigation (Figure 4.6).

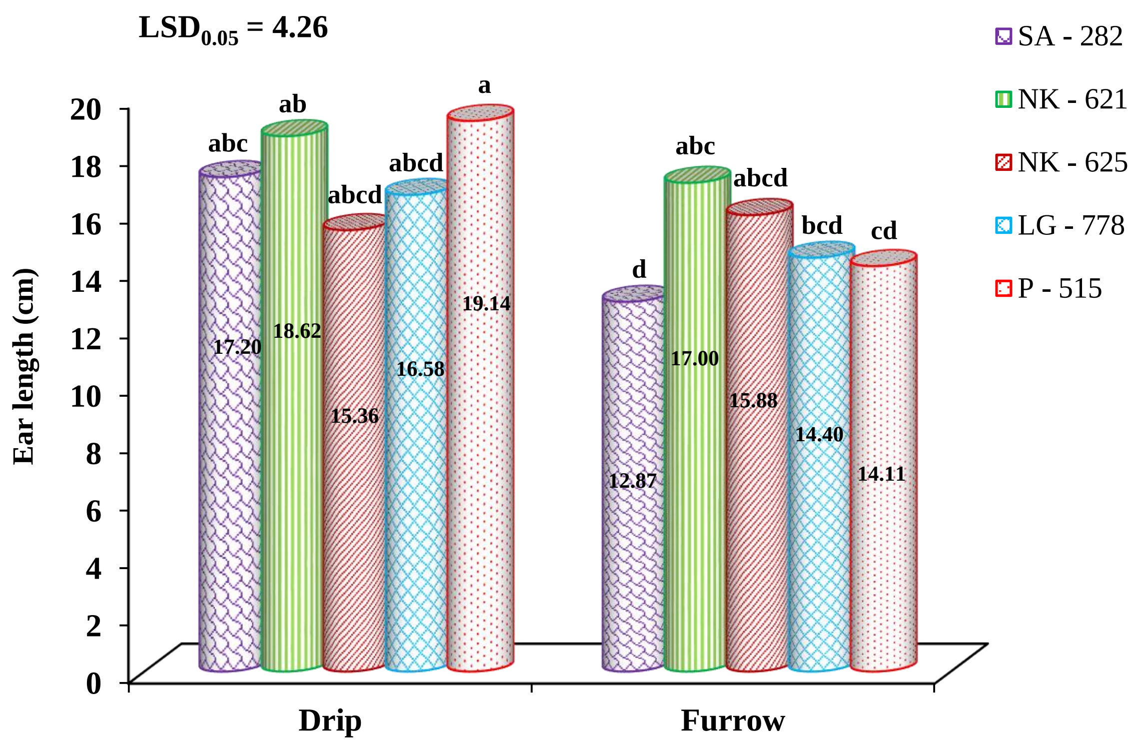


Figure 4.3 Ear length of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

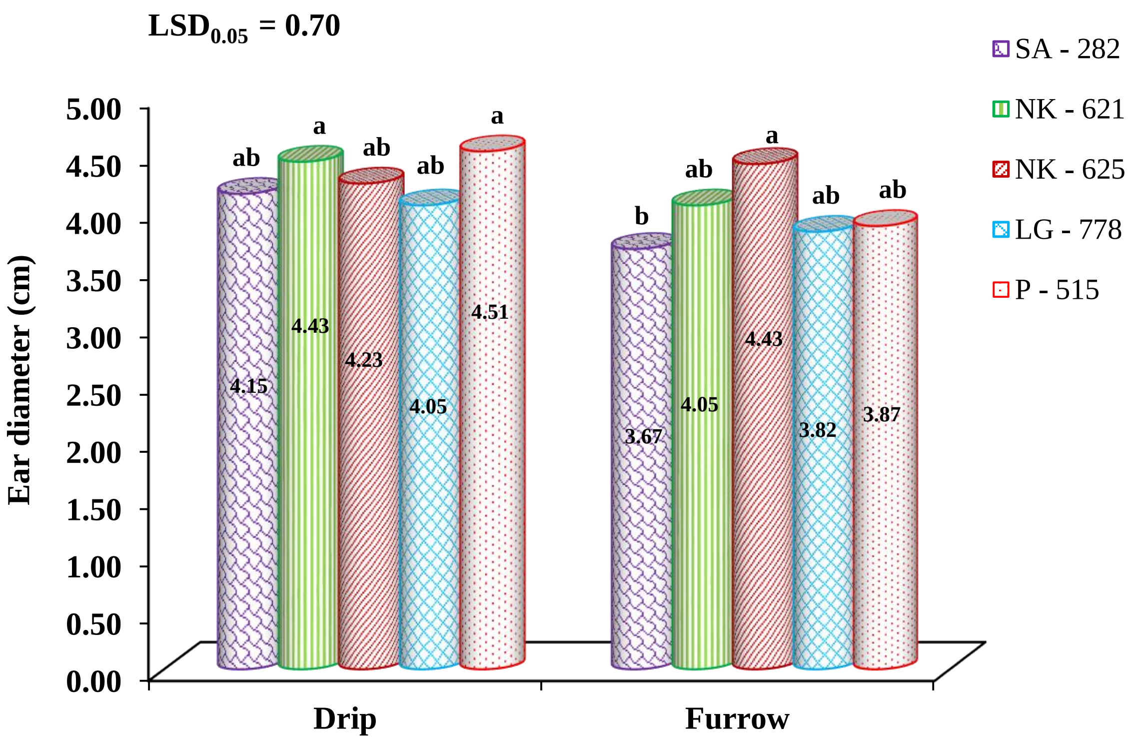


Figure 4.4 Ear diameter of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

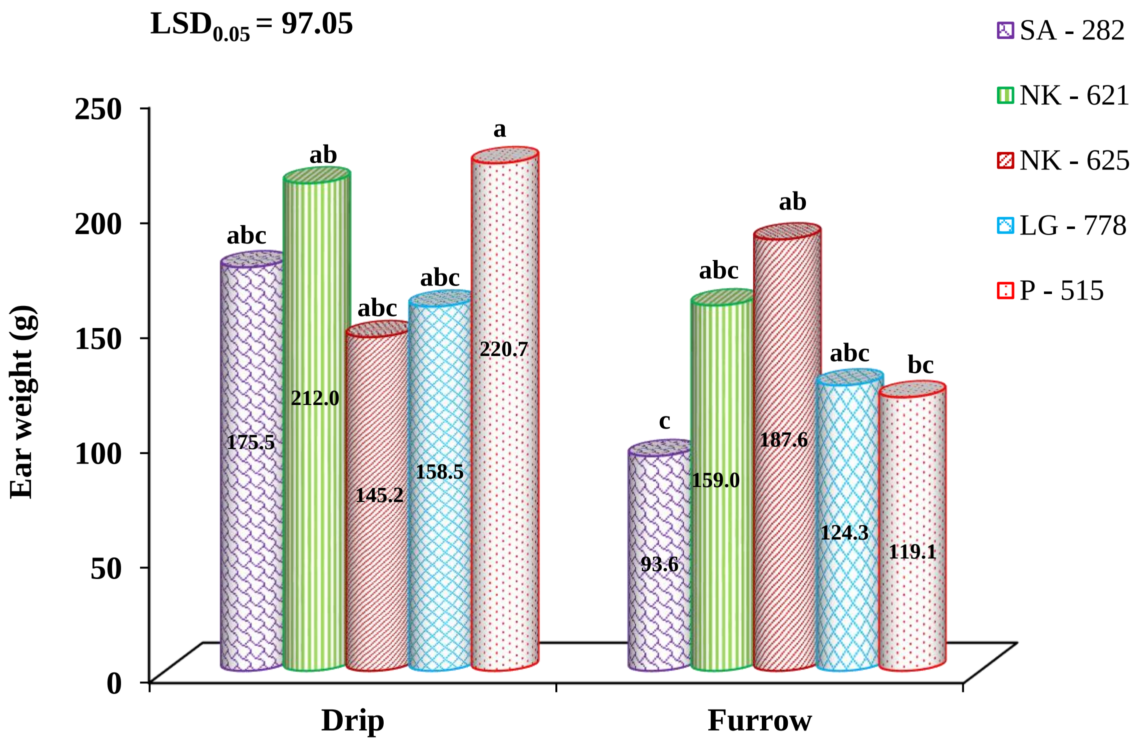


Figure 4.5 Ear weight of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

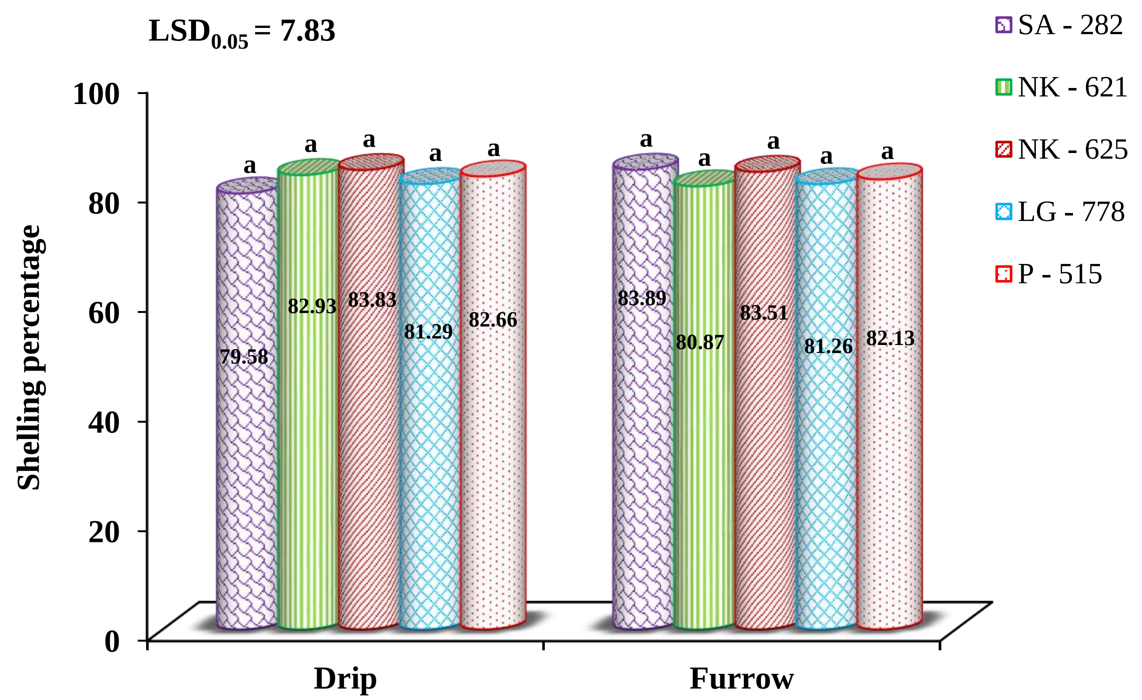


Figure 4.6 Shelling percentage of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

4.1.1.11 Grain yield

Although significantly different grain yield was not produced by irrigation methods and different varieties, the higher grain yields (5759.6 kg ha^{-1}) were recorded under drip irrigation and the lower grain yield by furrow irrigation (4218.6 kg ha^{-1}) were recorded (Table 4.1). Phene and Beale (1976) reported more corn yields (12 - 14%) in drip plots than the furrow and sprinkler irrigated plots. This establishes that shortest interval of drip irrigation provided the best plant development and finally the yield of crop. Among the varieties, the highest grain yields was gained from NK - 621 (6548.3 kg ha^{-1}) and P - 515 (5667.4 kg ha^{-1}) (Table 4.1) whereas the lowest grain yield was obtained from LG - 778 (3389.6 kg ha^{-1}).

Among all the treatments, the highest grain yields were produced by the variety P - 515 (8007.0 kg ha^{-1}), followed by NK - 621 (7166.0 kg ha^{-1}) and SA - 282 (5884.0 kg ha^{-1}) under drip irrigation (Figure 4.7). The varieties, P - 515 (3327.0 kg ha^{-1}), SA - 282 (3091.0 kg ha^{-1}) and LG - 778 (3385.0 kg ha^{-1}) produced obviously lower grain yield under furrow irrigation and the variety LG - 778 (3393.0 kg ha^{-1}) gave the lower grain yield under drip irrigation. The greater grain yield resulted by drip irrigation was possibly due to the greater grains number ear^{-1}.

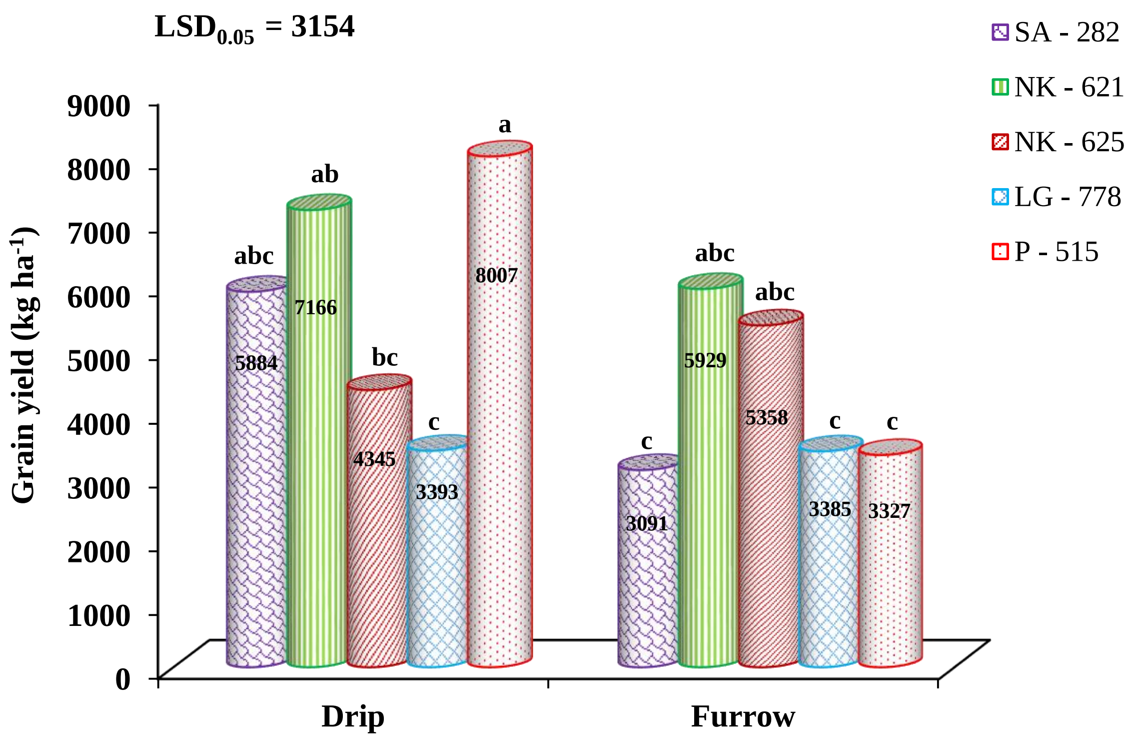


Figure 4.7 Grain yield as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

4.1.2 Agronomic characters

4.1.2.1 Plant height

The significant difference in plant height was found between two irrigation methods. Drip irrigation gave higher plant height (232.96 cm) and furrow irrigation produced lower plant height (169.99 cm) (Table 4.2). Plant height increased with irrigation as the plant advanced in growth in both irrigation methods (Figure 4.8). However, the plant height under drip irrigation was higher than that of furrow irrigation. Usoh, Nwa, Okokon, Nta, and Etim (2017) reported that the effect of drip and furrow irrigation methods were significantly different on plant height. Porro and Cassel (1986); Hernadez (1980) also found that decreased plant height in furrow irrigation method was due to water stress. Means comparison for varieties indicated the variety NK - 621 with the highest plant height (227.70 cm) and the variety SA - 282 with the lowest plant height (183.27 cm) were statistically different in plant height although there were no significant difference among the varieties. Among the responses of the varieties to irrigation methods, the maximum plant height was achieved from the variety P - 515 (262.3 cm) and NK - 621 (260.0 cm) under drip irrigation and the minimum plant height was found in the variety P - 515 (144.6 cm) under furrow irrigation (Figure 4.9).

4.1.2.2 Ear height

The ear height was significantly affected by irrigation methods (Table 4.2) and the higher ear height (107.28 cm) was observed in drip irrigation. Although there was no significant difference in plant height among the varieties, the highest ear height (111.83 cm) was noticed in the variety of NK - 621 followed by P - 515 (99.17 cm) while the shortest ear height (75.63 cm) was achieved in the variety LG - 778. Ear height increased with drip irrigation for the variety P - 515 and reduced with furrow irrigation for this variety P - 515 which was the lowest ear height as well among all mean values of ear height (Figure 4.10). Plant height and ear height responsed significantly to the type of irrigation in the variety P - 515 under this study.

4.1.2.3 Days to 50% tasseling

In this season, days to 50% tasseling was not significantly affected by irrigation methods and varieties (Table 4.2). The relatively longer days to 50% tasseling (71.07) was obtained by furrow irrigation and the relatively shorter days to 50% tasseling (70.27) was recorded from drip irrigation. The maximum days to 50% tasseling (73.33) was detected from LG - 778, followed by P - 515 (70.67) and the minimum days to 50% tasseling (68.67) was found in NK - 621 among the varieties. There was no significant interaction between irrigation methods and varieties (Table 4.2).

Table 4.2 Mean values of agronomic characters of maize as affected by two irrigation methods and five tested varieties in the dry season (November, 2017 to April, 2018)

Treatments	Plant height (cm)	Ear height (cm)	Days to 50% tasseling	Days to 50% silking	Water productivity (kg m^{-3})	Harvest index (HI)
A. Irrigation (I)						
Drip	232.96 a	107.28 a	70.27	74.00	1.26	0.29 a
Furrow	169.99 b	80.13 b	71.07	74.33	0.91	0.12 b
LSD $_{0.05}$	48.33	22.18	3.26	5.71	0.45	1.47
B. Varieties (V)						
SA - 282	183.27 b	91.30 ab	70.17 ab	73.33b	0.99 ab	0.21 ab
NK - 621	227.70 a	111.83 a	68.67 b	71.83 b	1.46 a	0.20 ab
NK - 625	200.80 ab	90.60 ab	70.50 ab	73.17 b	0.99 ab	0.19 b
LG - 778	192.13 ab	75.63 b	73.33 a	79.50 a	0.74 b	0.19 b
P - 515	203.47 ab	99.17 ab	70.67 ab	73.00 b	1.23 a	0.24 a
LSD $_{0.05}$	43.90	26.46	3.69	5.37	0.49	10.73
Pr>F						
I	0.030	0.034	0.402	0.825	0.079	0.001
V	0.313	0.109	0.164	0.057	0.057	0.201
I*V	0.254	0.123	0.527	0.331	0.081	0.907
CV% (A)	15.27	15.07	2.93	4.90	26.62	9.19
CV% (B)	17.80	23.08	4.27	5.92	36.66	20.15

Mean values in each column having the same letter are not significantly different at 5% level,
CV=Coefficient of variation

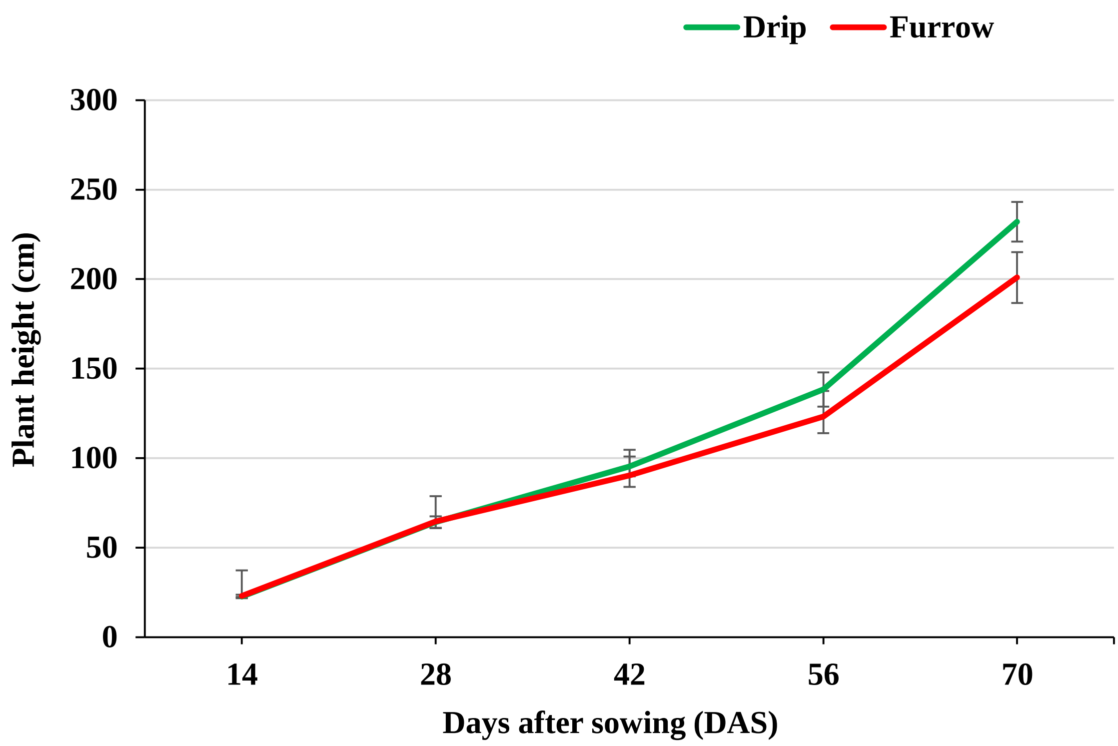


Figure 4.8 Mean plant height of five maize varieties as affected by two irrigation methods in the dry season (November, 2017 to April, 2018)

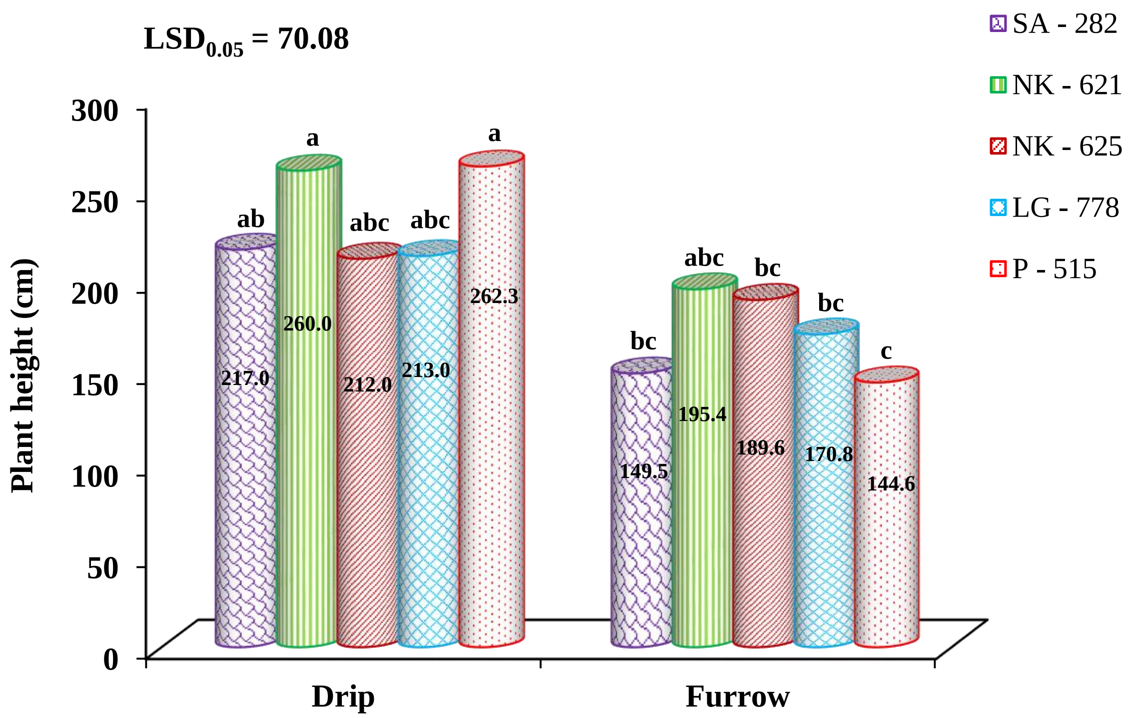


Figure 4.9 Plant height of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

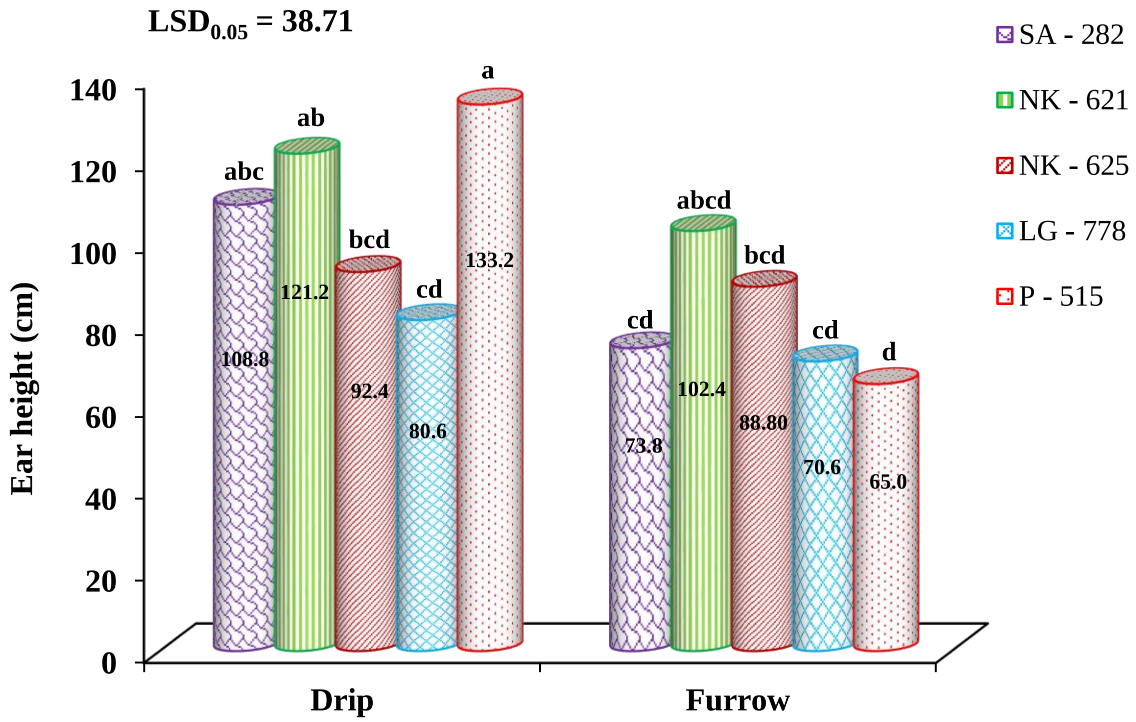


Figure 4.10 Ear height of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

4.1.2.4 Days to 50% silking

Days to 50% silking were not significantly different between irrigation methods and different varieties (Table 4.2). However, the variety LG - 778 showed the maximum days (79.50) to 50% silking among the varieties. As in the days to 50% tasseling, similar trend was observed in the days to 50% silking among the treatments.

4.1.2.5 Water productivity

In this season, the water productivity was not significantly different between irrigation methods, among the varieties and among all the treatments (Table 4.2). However, drip irrigation tended to give higher water productivity (1.26 kg m^{-3}) than furrow irrigation (0.91 kg m^{-3}) did. The highest water productivity (1.46 kg $m^{-3)}$ and (1.23 kg m^{-3}) were gained from the varieties (NK - 621 and P - 515), respectively, and the lowest water productivity (0.74 kg m^{-3}) was obtained from LG - 778 (Table 4.2). Although there were no significant interaction effect in water productivity, the variety P - 515 and NK - 621 with drip irrigation gave the highest water productivity 1.76 kg m^{-3} and 1.63 kg m^{-3}, respectively. The varieties, NK - 625 and LG - 778 with drip irrigation produced the lowest water productivity 0.88 kg m^{-3} and 0.71 kg m^{-3}, respectively. The varieties, LG - 778, P - 515 and SA - 282 with furrow irrigation produced the lowest water productivity 0.76 kg m^{-3}, 0.70 kg m^{-3} and 0.68 kg m^{-3}, respectively as shown in Figure (4.11).

4.1.2.6 Harvest index (HI)

Harvest index was highly significant different between irrigation methods (Table 4.2). Drip irrigation produced significantly higher harvest index (0.29) than furrow irrigation (0.12). The maximum harvest index (0.24) was recorded in the variety P - 515 whereas the minimum harvest index (0.19) was recorded in the variety NK - 625 and LG - 778 although the differences among the varieties were not significant. There was no significant interaction between irrigation methods and tested maize varieties on harvest index. However, among all the treatments, the highest harvest index (0.34) was obtained by drip irrigation in the variety P - 515 and the lowest harvest index was gained in furrow irrigation of all the varieties (Figure 4.12).

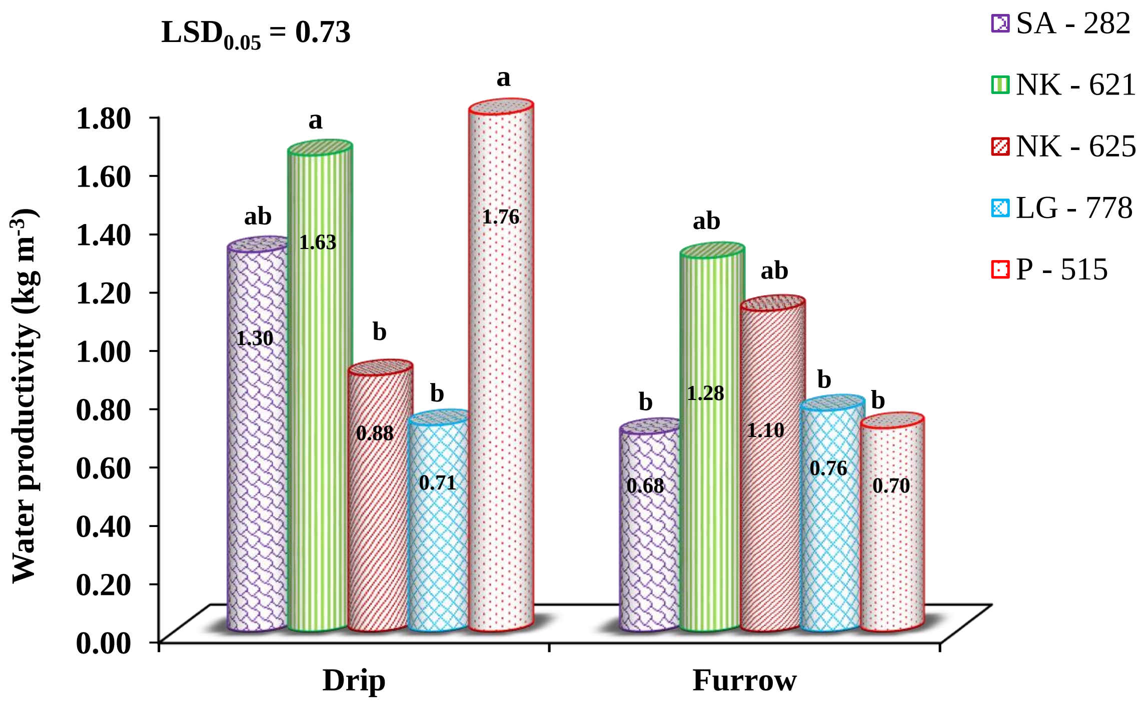


Figure 4.11 Water productivity of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

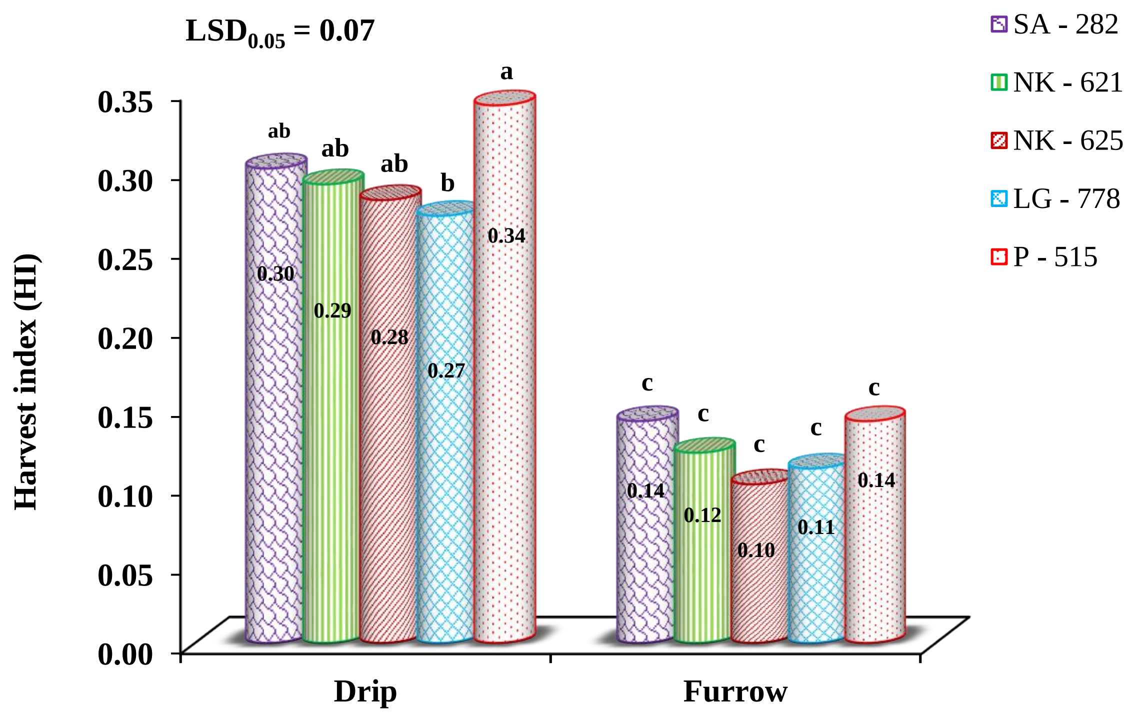


Figure 4.12 Harvest index of maize as affected by two irrigation methods and five varieties in the dry season (November, 2017 to April, 2018)

4.1.3 Correlation between yield and yield components of maize as affected by two irrigation methods

The correlation between yield and yield components of tested maize varieties as affected by two different irrigation methods were shown in Table (4.3). The grain yield was significantly and positively correlated with most of yield components except shelling percent and number of ear plant^{-1} as affected by two different irrigation methods. The high correlation of grain yield with thousand grains weight was reported by other researchers (Khazaei, Alikhani, Yari, & Khandan, 2010; Mohammadi & Prasanna, 2003). Bello, Abdulmaliq, Afolabi, and Ige (2010) stated that ear weight featured prominently in improving grain yield.

Except shelling percent and number of ear plant^{-1}, almost all of yield components were significantly and positively correlated with each other although the association between number of rows ear^{-1} and thousand grains weight was not significant under two different irrigation methods. You, Dong, Gu, Ma and Zhao (1998) noted that the number of rows ear^{-1} was positively correlated with number of grains row^{-1}. These results were in agreement with those of other researchers (Devi, Muhammad, & Mohammad, 2001; Kramer & Boyer, 1995; Mohsan, Singh, & Rao, 2002).

4.1.4 Correlation between yield and agronomic characters of maize as affected by two irrigation methods

Grain yield was highly and negatively correlated with days to 50% tasseling and days to 50% silking under two different irrigation methods (Table 4.4) indicating that early tasseling and silking date gave higher grain yield. The negative correlation indicates that increase in days to tasseling and silking could indirectly reduce yield (Malik, Malik, Hussain, Chughtai, & Javed, 2005). In turn, days to 50% tasseling and days to 50% silking were significantly and negatively correlated with ear height and plant height. It showed that 50% tasseling date was relatively earlier in the plants with increased plant height and ear height favoring longer grain filling period resulting higher grain yield. Days to 50% tasseling was significantly and positively correlated with days to 50% silking.

Grain yield was highly and positively correlated with ear height and plant height. In turn, ear height was highly and positively correlated with plant height. The strong correlation between ear height and plant height with grain yield suggested that tall plants with high ear placement gave better yields compared to the shorter plants with lower ear placement. Burak and Magoja (1991); Malvar, Revilla and Ordas (1994); Singha and Prodhan (2000); Golam et al. (2011) also found that grain yield was positively correlated with ear height. Lee, Jauh, Long, and Shung (2001) reported that plant height and ear height are positively correlated with each other.

Table 4.3 Correlation between yield and yield components of maize as affected by two irrigation methods in the dry season (November, 2017 to April, 2018)

	Grain yield	No. of grains row^{-1}	No. of rows ear^{-1}	Row length	No. of grains ear^{-1}	Thousand grains weight	Ear length	Ear diameter	Ear weight	No. of ear plant^{-1}
No. of grains row^{-1}	0.80**									
No. of rows ear^{-1}	0.37*	0.45*								
Row length	0.80**	0.94**	0.45*							
No. of grains ear^{-1}	0.79**	0.98**	0.60**	0.93**						
Thousand grains weight	0.82**	0.64**	0.32	0.74**	0.64**					
Ear length	0.86**	0.92**	0.42*	0.96**	0.91**	0.79**				
Ear diameter	0.81**	0.87**	0.57**	0.88**	0.89**	0.81**	0.85**			
Ear weight	0.84**	0.91**	0.49**	0.94**	0.92**	0.84**	0.94**	0.95**		
No. of ear plant^{-1}	0.30	0.14	0.17	0.12	0.17	-0.05	0.16	0.07	0.08	
Shelling percent	0.12	-0.08	0.03	-0.13	-0.06	-0.05	-0.20	0.05	-0.14	0.02

* Significant at 5% level ** Significant at 1% level

Table 4.4 Correlation between yield and agronomic characters of maize as affected by two irrigation methods in the dry season (November, 2017 to April, 2018)

	Grain yield	Days to 50% tasseling	Days to 50% silking	Ear height
Days to 50% tasseling	-0.66**			
Days to 50% silking	-0.79**	0.68**		
Ear height	0.93**	-0.67**	-0.74**	
Plant height	0.86**	-0.49**	-0.59**	0.91**

* Significant at 5% level, ** Significant at 1% level

4.2 Experiment During November, 2018 to April, 2019

4.2.1 Yield and yield components

4.2.1.1 Number of grains row^{-1}

The number of grains row^{-1} were not significantly affected by two irrigation methods. Relatively higher number of grains row^{-1} (37.93) were gained in drip irrigation and the lower number of grains row^{-1} (36.63) were achieved in furrow irrigation (Table 4.5). It may be due to the fact that no water deficit was experienced in drip irrigation and short term water deficit may be subjected at a certain growth stages of plant in furrow irrigation. If the water deficit occurred during silking, it can cause poor pollination or kernel set and decreased grains number per row. Khodarahmpour (2012) observed that water stress during pollination and grain filling stages can cause decreased grains number row^{-1}.

The number of grains row^{-1} were highly significantly different among the five tested varieties (Table 4.5). The maximum number of grains row^{-1} was obtained from NK - 621 (39.60) followed by LG - 778 (38.83) and P - 515 (38.11). The minimum number of grains row^{-1} was achieved from NK - 625 (33.31). There was no significant interaction between irrigation methods and tested varieties in number of grains row^{-1} (Table 4.5).

4.2.1.2 Number of rows ear^{-1}

Number of rows ear^{-1} were not significantly different between two irrigation methods (Table 4.5). However, significant differences among the varieties were observed by the maximum number of rows ear^{-1} (14.77) which was obtained from NK - 625 (Table 4.5). The number of rows ear^{-1} of other four tested varieties were not significantly different. Among all the treatments, number of rows ear^{-1} were not significantly different. It can be assumed that varietal response of maize in the number of rows ear^{-1} does not depend on irrigation because it is a varietal character. Elzubeir and Mohamed (2011) stated that number of rows ear^{-1} of maize was not significantly different by irrigation intervals.

4.2.1.3 Row length

Row length of maize was not significantly different between two irrigation methods (Table 4.5). The longer row length (18.82 cm) was resulted in the drip irrigation and the shorter row length (15.97 cm) was gained in furrow irrigation (Table 4.5). However, row length of maize was significantly different among the varieties (Table 4.5). The longer row length (18.78 cm) was achieved from LG - 778 (18.78 cm), NK - 621 (18.60 cm) and P - 515 (17.92 cm), while the shorter row length was obtained from the varieties SA - 282 (16.19 cm) and NK - 625 (15.48 cm).

Table 4.5 Mean values of yield and yield components of maize as affected by two irrigation methods and five tested varieties in the dry season (November, 2018 to April, 2019)

Treatments	No. of grains row $^{-1}$	No. of rows ear $^{-1}$	Row length (cm)	No. of grains ear $^{-1}$	Thousand grains weight (g)	Ear length (cm)	Ear diameter (cm)	Ear weight (g)	No. of ear plant $^{-1}$	Shelling %	Yield (kg ha^{-1})
A. Irrigation (I)											
Drip	37.93	14.35	18.82	544.36	334.85 a	20.28 a	5.01	279.33	1.12	83.75	12725.00 a
Furrow	36.63	13.79	15.97	505.12	276.02 b	18.87 b	4.64	207.52	1.05	82.53	8736.00 b
LSD $_{0.05}$	4.51	1.44	3.36	114.53	50.87	0.93	0.49	72.99	0.11	2.76	3157.40
B. Varieties (V)											
SA - 282	36.55 b	14.01 b	16.19 b	511.75 bc	271.80 b	17.74 c	4.59 d	205.47 d	1.40 a	85.90 a	11914.00 a
NK - 621	39.60 a	14.13 b	18.60 a	559.81 a	337.48 a	21.32 a	4.97 ab	283.97 a	1.03 b	82.85 bc	11556.00 ab
NK - 625	33.31 c	14.77 a	15.48 b	492.96 c	332.55 a	18.21 c	5.08 a	255.83 ab	1.00 b	84.11 ab	11092.00 ab
LG - 778	38.83 ab	13.93 b	18.78 a	541.09 ab	293.12 b	20.57 ab	4.80 bc	247.55 bc	1.00 b	80.76 c	10136.00 bc
P - 515	38.11 ab	13.53 b	17.92 a	518.09 abc	292.23 b	20.04 b	4.68 cd	224.31 cd	1.00 b	82.09 bc	8955.00 c
LSD $_{0.05}$	2.94	0.62	1.16	47.83	24.48	0.98	0.17	29.64	0.08	2.27	1535.90
Pr>F											
I	0.339	0.236	0.067	0.278	0.038	0.022	0.087	0.051	0.129	0.196	0.032
V	<0.001	0.011	<0.001	0.070	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00,	<0.001
I*V	0.507	0.132	<0.001	0.183	0.218	<0.001	0.270	0.033	<0.001	0.272	0.409
CV% (A)	7.70	6.55	12.31	13.89	10.60	3.05	6.52	19.09	6.72	2.12	18.73
CV% (B)	6.46	3.64	5.47	7.45	6.55	4.11	3.04	9.95	6.72	2.23	11.69

Mean values in each column having the same letter are not significantly different at 5% level
CV=Coefficient of variation

4.2.1.4 Number of grains ear^{-1}

Although the effect of drip irrigation and furrow irrigation were not significantly different in number of grains ear^{-1}, the number of grains ear^{-1} of drip irrigation (544.36) was numerically higher than that of furrow irrigation (505.12) (Table 4.5). Yazar, Sezen and Gencel (2012) found that the maximum total grains ear^{-1} was achieved from full irrigation using drip irrigation method.

No significant differences in number of grains ear^{-1} was observed also among the varieties (Table 4.5). Nevertheless, the maximum number of grains ear^{-1} (559.81) was resulted from the variety NK - 621 and followed by LG - 778 (541.09). The minimum number of grains ear^{-1} (492.96) was gained from the variety NK - 625. Number of grains ear^{-1} is one of the most important component to enhance grain yield.

There was no significant interaction between irrigation and varieties in number of grains ear^{-1}. It showed that the response of varieties in number of grains ear^{-1} was not influenced by irrigation methods.

4.2.1.5 Thousand grains weight

Thousand grains weight of maize was significantly affected by irrigation methods (Table 4.5). The higher thousand grains weight (334.85 g) was obtained from drip irrigation whereas the lower thousand grains weight (276.02 g) was resulted from furrow irrigation. Khan, Hussain and Iqbal (2001); Abbas, Hussain, Ahmad and Wajid (2005) found that thousand grains weight in maize was reduced by increasing water stress. In this study, short term water deficit occurred in furrow irrigation at certain growth stages affecting 1000-grains weight.

Thousand grains weight of the five varieties were significantly different (Table 4.5). The varieties NK - 621 (337.48 g) and NK - 625 (332.55 g) produced greater 1000-grains weight which were significantly higher than those of the other varieties which were statistically similar each other (Table 4.5).

No significant interaction between irrigation methods and five tested varieties were observed in thousand grains weight (Table 4.5). However, the highest thousand grains weight (378.96 g) was found in variety NK - 621, followed by NK - 625 (361.83 g) and P - 515 (329.26 g) under drip irrigation. The lowest thousand grains weights (256.46 g and 255.20 g) were gained in varieties SA - 282 and P - 515, respectively under furrow irrigation (Figure 4.13).

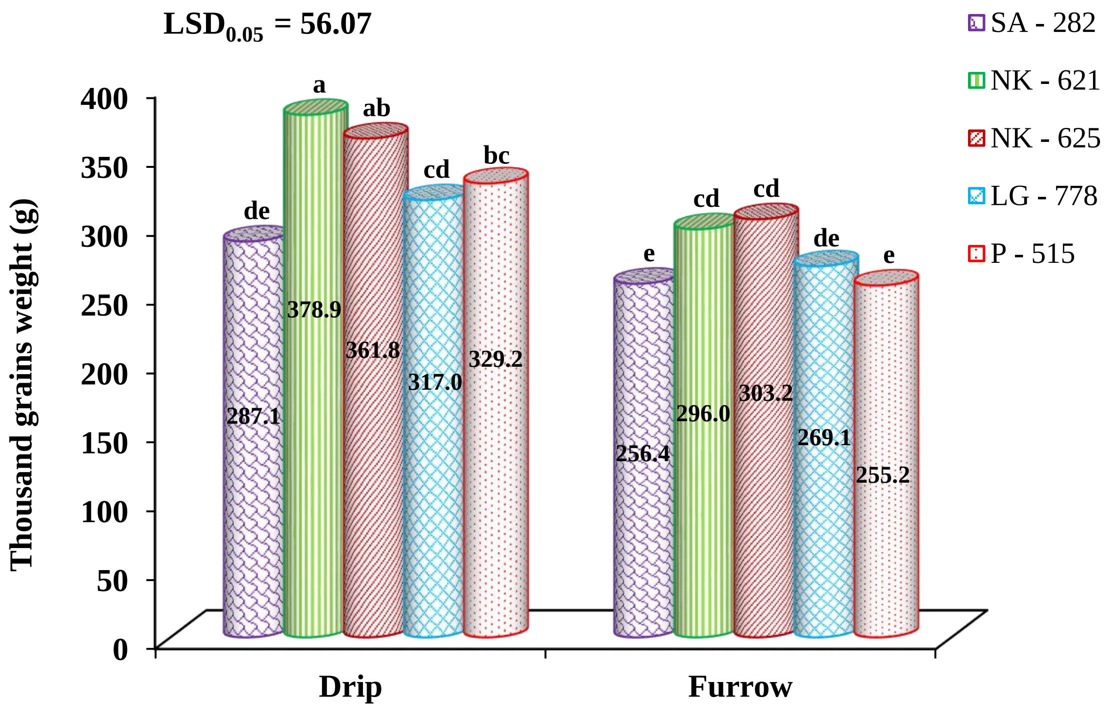


Figure 4.13 Thousand grains weight of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.1.6 Ear length

Significantly different ear length was resulted by irrigation methods, and also by tested five varieties (Table 4.5). The longer ear length (20.28 cm) was obtained by drip irrigation and the shorter ear length (18.87 cm) was gained in furrow irrigation (Table 4.5). The maximum ear length (21.32 cm) was found from the variety NK - 621, followed by the varieties LG - 778 (20.57 cm) and P - 515 (20.04 cm). The minimum ear lengths (17.74 cm and 18.21 cm) were achieved from the varieties SA - 282 and NK - 625 respectively.

Significant interaction between irrigation methods and varieties was observed in ear length indicating that ear length of maize varieties varied with irrigation methods. Average ear length of maize affected by irrigation methods and varieties ranged from 17.07 cm to 22.20 cm (Figure 4.14). The maximum ear length (22.20 cm) was obtained from the variety NK - 621, followed by P - 515 (21.76 cm) and LG - 778 (20.81 cm) under drip irrigation. The minimum ear length (17.07 cm) was achieved in the variety NK - 625 under furrow irrigation and the variety SA - 282 under drip irrigation although SA - 282 produced greater ear length in furrow irrigation (Figure 4.14).

4.2.1.7 Ear diameter

Although ear diameter was not significantly different between irrigation methods, significant differences in ear diameter were found among the varieties. The maximum ear diameter (5.08 cm) was resulted from the variety NK - 625 followed by NK - 621 (4.97 cm), whereas the minimum ear diameter (4.59 cm) was attained from SA - 282 among the varieties (Table 4.5). The interaction between irrigation and varieties of maize was not significant in ear diameter reflecting that ear diameter of maize varieties did not change because of irrigation methods.

4.2.1.8 Ear weight

No significant difference in ear weight was observed between irrigation methods (Table 4.5). However, relatively greater ear weight (279.33 g) was resulted in drip irrigation while relatively lower ear weight (207.52 g) was found in furrow irrigation. Ear weight was highly significantly different among the varieties (Table 4.5). The variety NK - 621 gave the highest ear weight (283.97 g), followed by NK - 625 (255.83 g), and SA - 282 gave the lowest ear weight (205.47 g) (Table 4.5). It indicated that ear weights were significantly varied depending on the variety. Increased ear length, ear diameter and thousand grains weight may contribute to increase ear weight of maize variety.

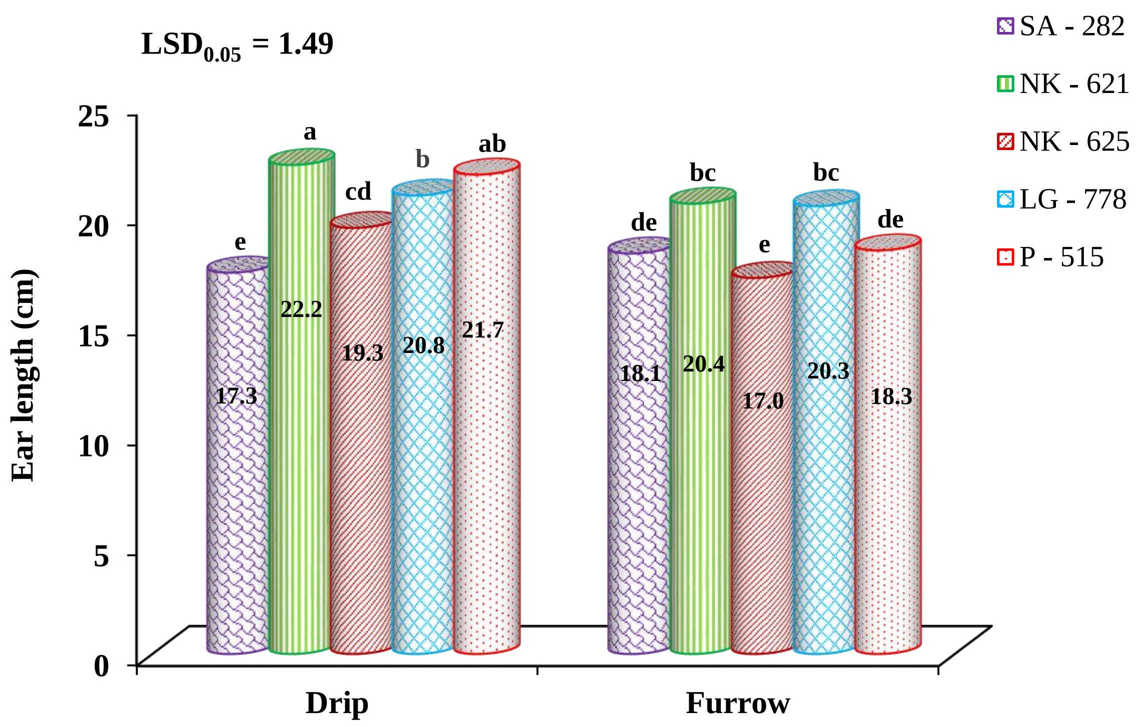


Figure 4.14 Ear length of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.1.9 Number of ear plant^{-1}

Number of ear plant^{-1} was not significantly different between irrigation methods (Table 4.5).The relatively higher number of ear plant^{-1} (1.12) was resulted from drip irrigation and the lower number of ear plant^{-1} (1.05) was obtained from furrow irrigation. There were significant differences in ear plant^{-1} among varieties. The variety SA - 282 produced more ear plant^{-1} (1.40) than the other four varieties which produced only one ear plant^{-1}.

The interaction between irrigation methods and varieties was significant in number of ear plant^{-1} (Table 4.5). Among the treatments, the highest number of ear plant^{-1} (1.60) was obtained from the variety SA - 282 under drip irrigation followed by variety SA - 282 (1.20) under furrow irrigation (Figure 4.15). The ear number of other four varieties did not increase regardless of irrigation methods. Only the variety SA - 282 was obviously affected by irrigation method.

4.2.1.10 Shelling percentage

Shelling percentage is one of the most important components in order to gain high yield. It was found that irrigation methods did not significantly affect on shelling percent of maize (Table 4.5). However, the drip irrigation produced relatively higher shelling percent (83.75%) as compared to furrow irrigation (82.53%). Significant differences in shelling percent was observed among the five tested varieties. The maximum shelling percentage (85.90%) was achieved from SA - 282 variety followed by NK - 625 (84.11%). The minimum shelling percentage (80.76%) was obtained from LG - 778.

The interaction effect between irrigation methods and varieties was not significant (Table 4.5). Among all the treatments, however, the highest shelling percentage was gained by furrow irrigation in variety SA - 282 (86.27%) and the lowest shelling percentage was obtained in the variety LG - 778 (80.12%) under furrow irrigation (Figure 4.16). Among the varieties with drip irrigation, it was also found that SA - 282 (85.54%) and LG - 778 (81.40%) showed the maximum shelling percentage and minimum shelling percentage respectively. It reflected that shelling percent was related to the variety.

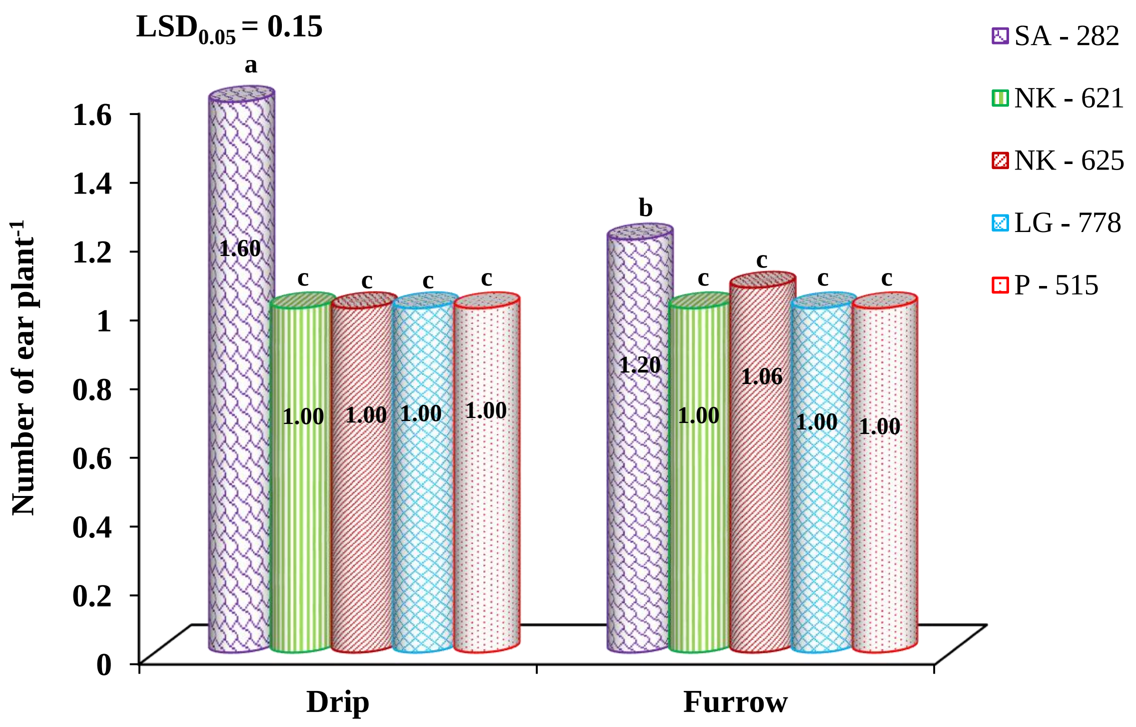


Figure 4.15 Number of ear plant^{-1} of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

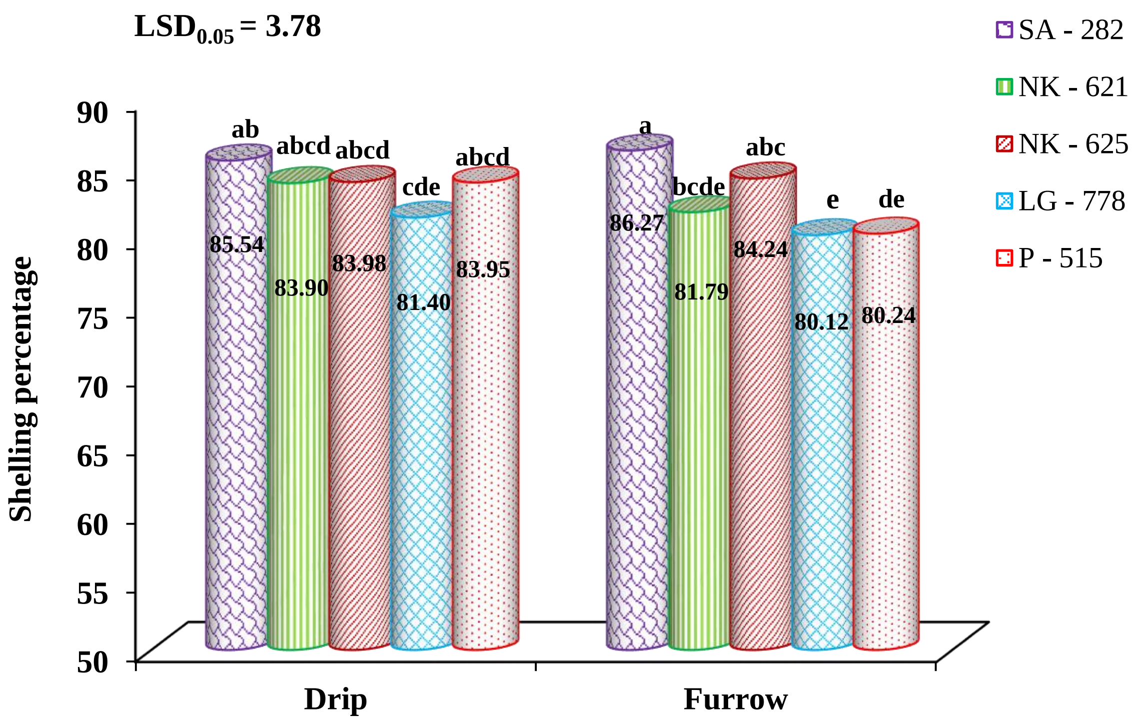


Figure 4.16 Shelling percentage of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.1.11 Grain yield

Significantly different grain yields were resulted by irrigation methods and maize varieties (Table 4.5). The higher grain yields (12725.0 kg ha^{-1}) were gained under drip irrigation whereas the lower yield was achieved in furrow irrigation (8736.0 kg ha^{-1}). The greater grain yield resulted by drip irrigation was possibly due to the significant greater ear length and thousand grains weight. It was found that all the five varieties gave high yield. Among the varieties, the highest grain yields were gained from SA - 282 (11914.0 kg ha^{-1}) probably because of its higher number of ear $plant^{-1}$ and higher shelling %, followed by the varieties NK - 621 (11556.0 kg ha^{-1}) and NK - 625 (11092.0 kg ha^{-1}) (Table 4.5). The lowest grain yield was obtained from the variety P - 515 (8955.0 kg ha^{-1}). It may be due to its lower yield components, particularly in thousand grains weight, ear weight, ear diameter and shelling % among the tested varieties.

Although there was no significant interaction effect between irrigation methods and varieties on yield (Table 4.5), the highest grain yields were noticed in the variety NK - 621 (14360.0 kg ha^{-1}) and SA - 282 (13860.0 kg ha^{-1}) under drip irrigation (Figure 4.17). The varieties, P - 515 (6840.0 kg ha^{-1}), LG - 778 (8741.0 kg ha^{-1}) and NK - 621 (8752.0 kg ha^{-1}) produced obviously lower grain yield under furrow irrigation (Figure 4.17). Although number of grains ear^{-1} in variety SA - 282 was not obviously higher, a slightly increased amount of grains ear^{-1} also provided to increase yields.

Elzubeir and Mohamed (2011) found that effect of irrigation intervals was significantly different on grain yield. Yang, Fan and Hsiang (1994); Ahmed (2002); Ahmed and El Hag (1999) observed that prolonged watering intervals decreased plant grain yield and grain yield ha^{-1}**.** Dhillon, Thind, Saxena, Sharma and Malhi (1995) stated that extreme water stress at different stages of crop development can cause reduced yield significantly.

In this study, furrow irrigation was applied four times at 25 days interval and drip irrigation was applied twenty four times at 4 days interval throughout the whole season. Short term water deficit may be resulted at certain plant growth stages in flowering and grain-filling stage of maize plant grown with furrow irrigation, but drip irrigation seemed to mitigate or may cause free from water deficit at any stage of the plant leading to increase yield due to better grain filling.

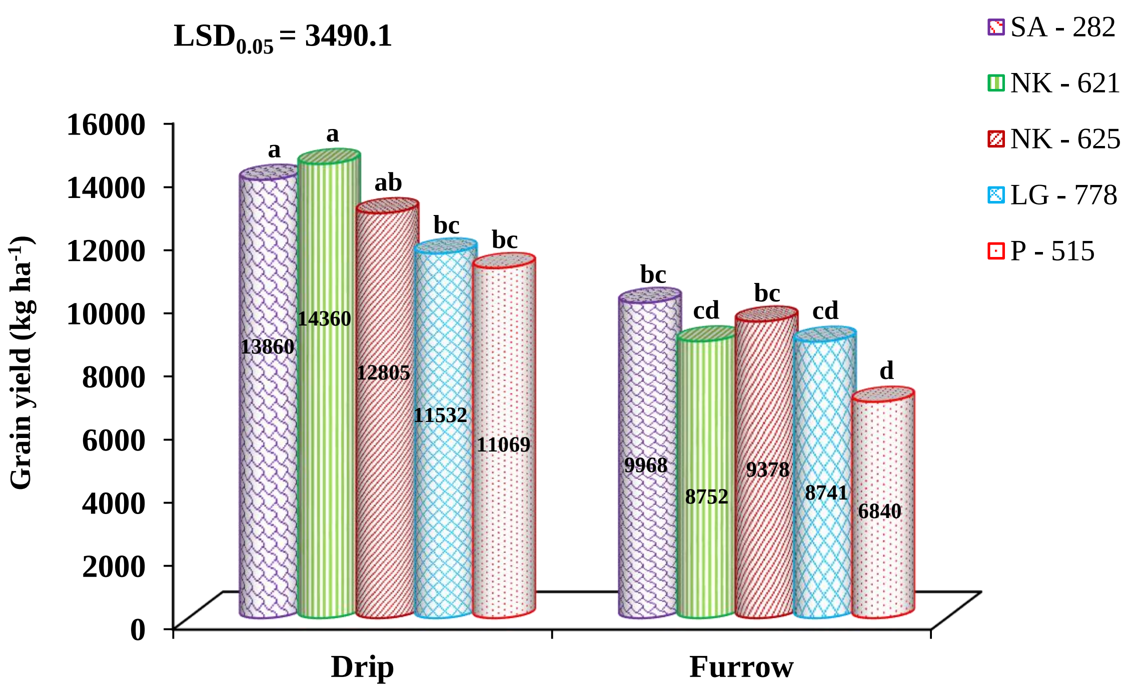


Figure 4.17 Grain yield as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.2 Agronomic characters

4.2.2.1 Plant height

The plant height was measured at 14 days interval from 14 to 70 (DAS). The plant height increased continuously as the plants advanced in growth till 70 DAS in both irrigation methods (Figure 4.18). However, since 28 DAS, plant height was significantly different between drip and furrow irrigation. The plant height under furrow irrigation was lower than that of drip irrigation. The reason might be due to short term water deficit that may occur in furrow irrigation. On the other hand, the plant grown by drip irrigation did not suffer water deficit and it may lead to relatively longer internodes and plant height. Kefale and Ranamukhaarachchi (2004) also found that moisture deficit during early vegetative stage reduced plant height and ear height leading to shorter internodes. Drip irrigation gave significantly higher plant height (265.91 cm) than furrow irrigation (229.46 cm) did (Table 4.6). Elzubeir and Mohamed (2011); Abdelgadir (2002) and Abu Hasbro (2002) reported that the water stress has small effect on internodes elongation. Elzubeir and Mohamed (2011) found in their study that the tallest plant height was obtained in short irrigation interval and plant height decreased as irrigation interval prolonged.

There were significant differences in plant height among the five tested varieties (Table 4.6). The highest plant height (267.80 cm) was observed in the variety LG - 778, and the lowest plant height (230.55 cm) was found in the variety SA - 282.

There were no significant interaction of irrigation methods and varieties in the plant height of maize (Table 4.6) indicating that the variation in plant height was just due to irrigation methods and varieties. In other word, the plant height of all tested varieties showed the increased plant height with drip irrigation. Among all the treatments, the highest plant height was achieved from the variety LG - 778 (281.53 cm) under drip irrigation whereas the lowest plant height was found in the varieties SA - 282 and P - 515 under furrow irrigation (Figure 4.19).

Table 4.6 Mean values of agronomic characters of maize as affected by two irrigation methods and five tested varieties in the dry season (November, 2018 to April, 2019)

Treatments	Plant height (cm)	Ear height (cm)	Days to 50% tasseling	Days to 50% silking	Water productivity (kg m^{-3})	Harvest index (HI)
A. Irrigation (I)						
Drip	265.91 a	132.07 a	66.13 b	66.80 b	1.81 a	0.16
Furrow	229.46 b	112.01 b	70.73 a	71.66 a	1.24 b	0.16
LSD $_{0.05}$	8.49	6.40	1.31	1.03	0.45	0.01
B. Varieties (V)						
SA - 282	230.55 c	112.93 b	67.50 c	67.50 d	1.70 a	0.15 b
NK - 621	246.70 b	120.50 b	68.33 b	69.50 b	1.65 ab	0.18 a
NK - 625	250.25 b	122.70 b	68.33 b	68.33 cd	1.58 ab	0.15 b
LG - 778	267.80 a	121.23 b	68.33 b	69.17 bc	1.45 bc	0.15 b
P - 515	243.13 bc	132.84 a	69.66 a	71.66 a	1.27 c	0.16 b
LSD $_{0.05}$	16.13	9.76	0.73	0.90	0.22	0.01
Pr>F						
I	<0.001	<0.001	<0.001	<0.001	0.032	0.885
V	<0.001	<0.001	<0.001	<0.001	<0.001	0.011
I*V	0.321	0.308	<0.001	0.042	0.405	0.191
CV% (A)	2.18	3.34	1.22	0.95	18.77	6.81
CV% (B)	5.32	6.54	0.87	1.06	11.75	6.77

Mean values in each column having the same letter are not significantly different at 5% level,
CV=Coefficient of variation

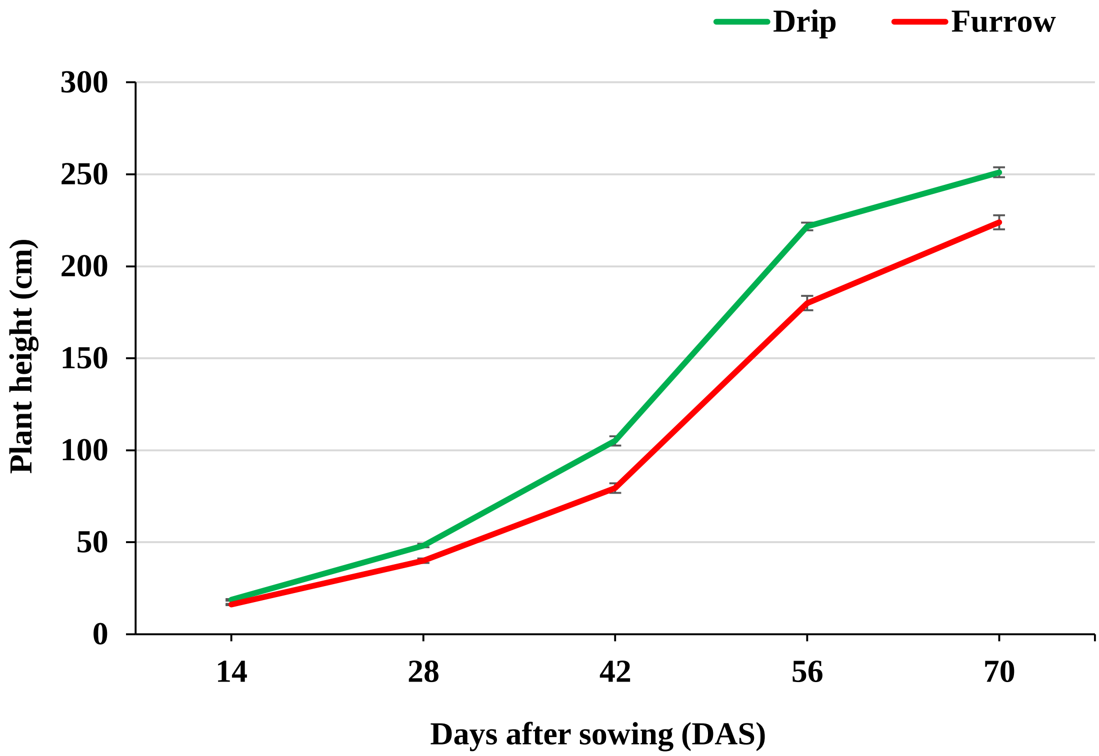


Figure 4.18 Mean plant height of five maize varieties as affected by two irrigation methods in the dry season (November, 2018 to April, 2019)

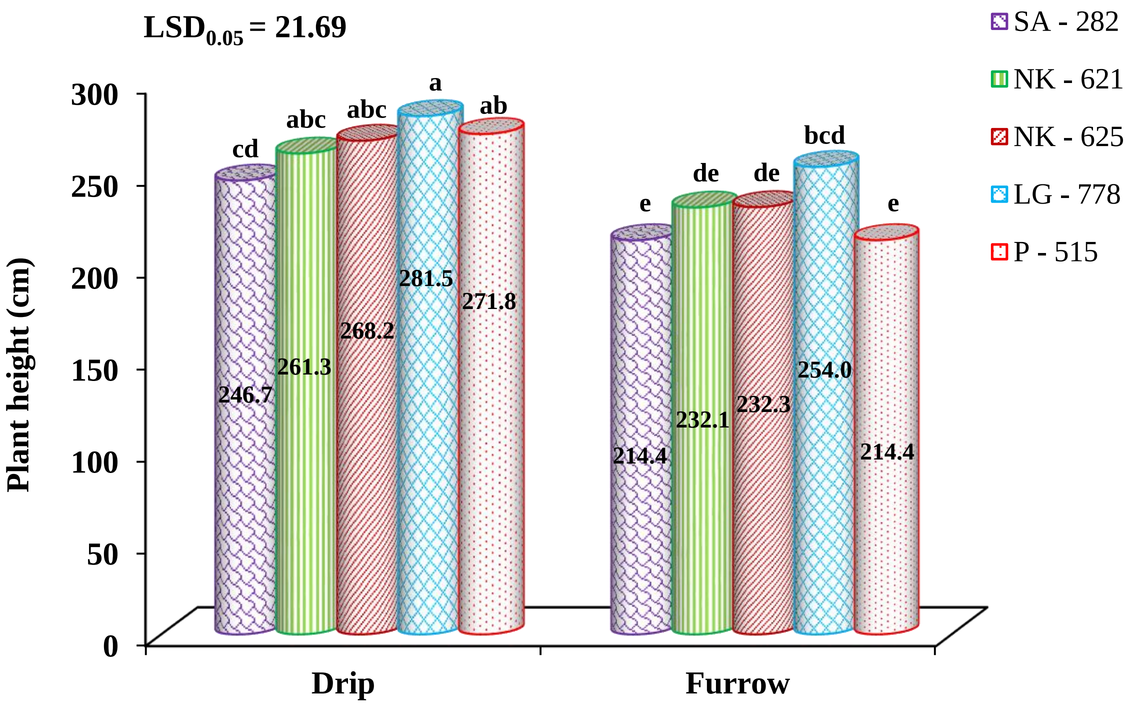


Figure 4.19 Plant height of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.2.2 Ear height

The ear height was significantly affected by irrigation methods and varieties (Table 4.6). The higher ear height (132.07 cm) was observed in drip irrigation and the lower ear height (112.01 cm) was found in furrow irrigation. Among the tested varieties, the highest ear height (132.84 cm) was noticed in the variety P - 515 while the shortest ear height (112.93 cm) was achieved in the variety SA - 282. Plant height and the height of main ear are in close correlation with each other. It depends on the variety or the environment, but is likely to be the same height within a population. Szőke (2015) found that the plant and ear height not only depend on the genetic background of the varieties, but are also influenced by many environmental effects and by the growing method. Hansen (1975); Haqqani and Pandey (1994) also found that ear height positively correlated with plant height. As in the plant height, no significant interaction between irrigation methods and varieties was found in ear height (Table 4.6) and all the tested varieties showed increased ear height in drip irrigation method (Figure 4.20).

4.2.2.3 Days to 50% tasseling

Average number of days to 50% tasseling of maize by the drip irrigation and furrow irrigation were significantly different (Table 4.6). Days to 50% tasseling of maize by drip irrigation (66.13) was significantly shorter than that by furrow irrigation (70.73). Water deficit during reproductive period increases the tasseling-silking interval (Herrero & Johnson, 1981) and shortens the grain filling period (Westgate, 1994), both effects reducing the grain yield. Oktem (2008) found that days to tasseling was longer with increasing water stress. Edmeades, Bolaños and Lafitte (1990) also observed that days to tasseling was longer due to water stress conditions. Robins and Domingo (1953) reported that even 2 or 7 days long water stress in the tasselling stage leads to grain yield reduction up to 22 and 50%, respectively.

Days to 50% tasseling of maize was significantly different among five tested varieties (Table 4.6). The maximum days (69.66) to 50% tasseling was achieved from variety P - 515 and the minimum days (67.50) to 50% tasseling was found in SA - 282. Days to 50% tasseling of the varieties NK - 621, NK - 625 and LG - 778 were not significantly different with each other.

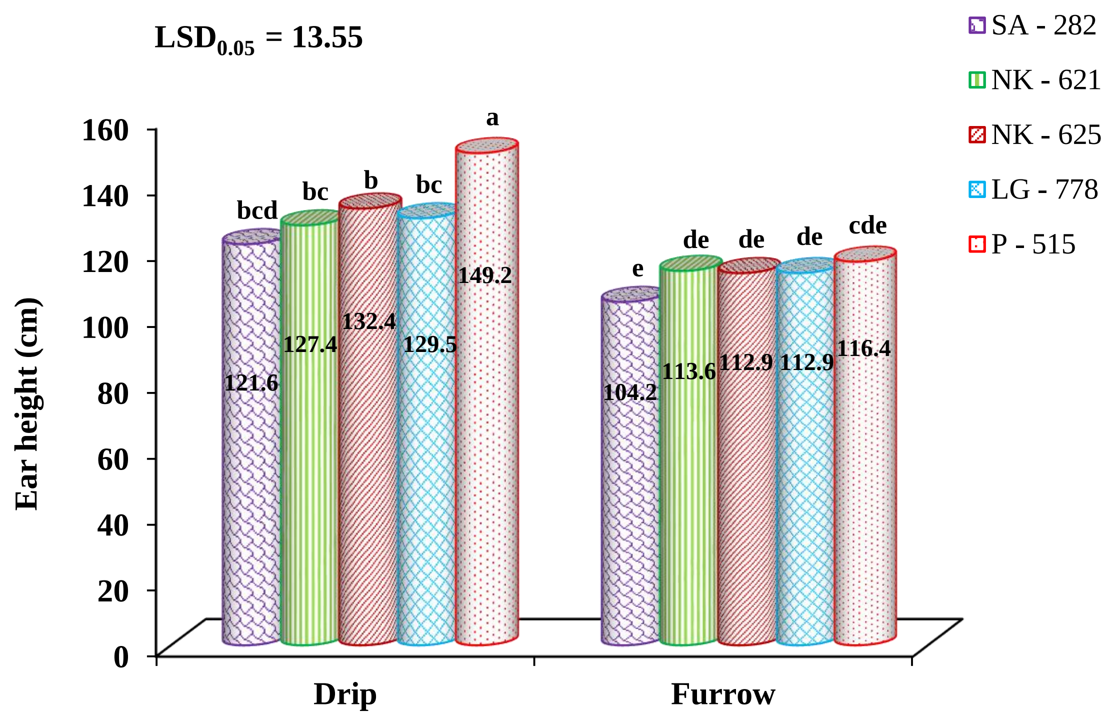


Figure 4.20 Ear height of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

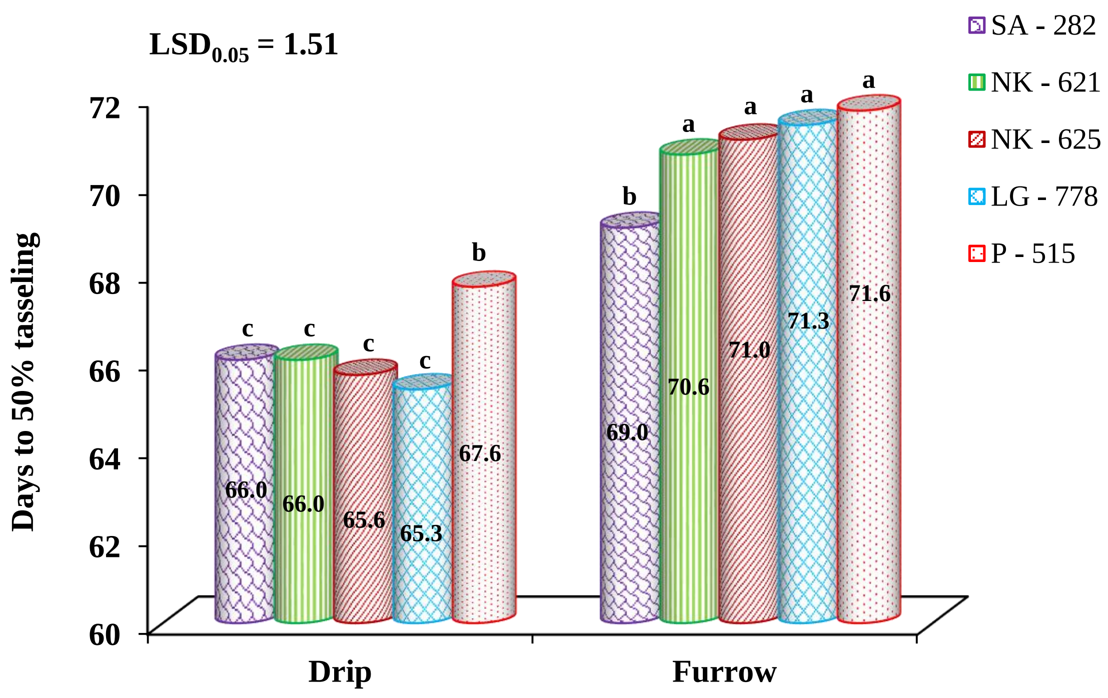


Figure 4.21 Day to 50% tasseling of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

There was significant interaction effect of irrigation methods and tested varieties on days to 50% tasseling (Table 4.6). It reflected that response in days to 50% tasseling of maize varieties varied with irrigation methods. Average number of days to 50% tasseling of maize affected by the combined effect ranged from 65.33 to 71.66. The maximum days to 50% tasseling was obtained in varieties P - 515 (71.66), LG - 778 (71.33), NK - 625 (71.00) and NK - 621 (70.66) by furrow irrigation (Figure 4.21). The minimum days to 50% tasseling was resulted in LG - 778, NK - 625, NK - 621 and SA - 282 by drip irrigation. Therefore, the number of days to 50% tasseling of the varieties, particularly LG - 778, NK - 621, NK - 625 and SA - 282 was significantly reduced in drip irrigation.

4.2.2.4 Days to 50% silking

Days to 50% silking of maize were significantly affected by irrigation methods, the varieties and their interaction effect (Table 4.6). The maximum days to 50% silking (71.66) was achieved from furrow irrigation while the minimum days to 50% silking (66.80) was obtained from drip irrigation. The variety P - 515 showed the maximum days (71.66) to 50% silking among the varieties, whereas the variety SA - 282 gave the minimum number of days (67.50) to 50% silking.

Average number of days to 50% silking of maize varieties with two irrigation methods ranged from 65.66 to 74.33, and the maximum days to 50% silking (74.33) was obtained in variety 515 by furrow irrigation, followed by NK - 621 (72.33) (Figure 4.22). The minimum days to 50% silking (65.66) was gained in NK - 625 by drip irrigation. This result indicated that the response of maize varieties, particularly NK - 621, NK - 625, LG - 778 and SA - 282, in days to 50% silking dramatically changed with irrigation methods, as in days to 50% tasseling. Cakir (2004) found that water stress occurring during reproductive stages reduced plant height and delayed silking, as well as leaf area development. Ge, Sui, Bai, Tong and Sun (2012) also observed that the result of water stress was a substantial deterioration in ear formation and poor grain filling, leading to significantly fewer kernels in each ear. Drought stress in reproductive stages reduced the time of pollen shedding and delayed silk development, while cool, moist conditions are responsible for an increase in silk and pollen production.

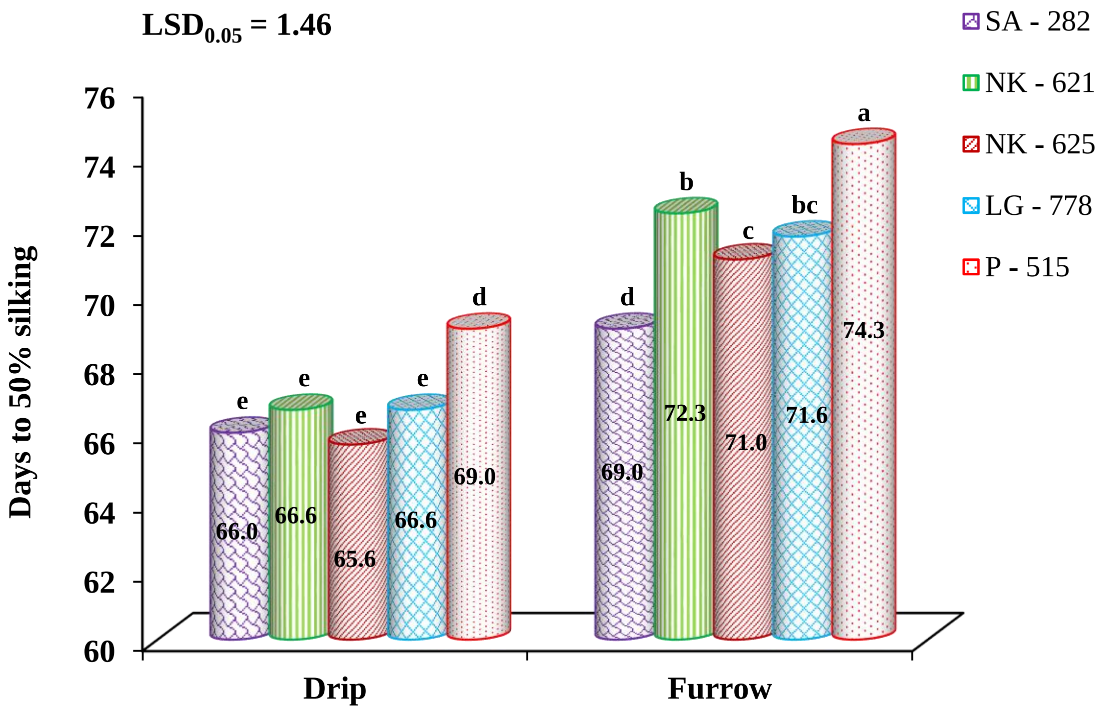


Figure 4.22 Day to 50% silking of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.2.5 Water productivity

The water productivity of maize was significantly different between irrigation methods and among the tested varieties (Table 4.6). Drip irrigation gave (1.81 kg m^{-3}) which was significantly higher than that produced by furrow irrigation (1.24 kg m^{-3}). Among the varieties, the highest water productivity (1.70 kg m^{-3}) was gained from SA - 282, followed by NK - 621 (1.65 kg m^{-3}) and NK - 625 (1.58 kg m^{-3}), respectively. The lowest water productivity (1.27 kg m^{-3}) was achieved from the variety P - 515 (Table 4.6). Although there were no significant interaction effect of irrigation methods and varieties, the variety NK - 621 and SA - 282 with drip irrigation gave the highest water productivity, 2.05 kg m^{-3} and 1.98 kg m^{-3} respectively. The variety P - 515 with furrow irrigation produced the lowest water productivity (0.97 kg m^{-3}) (Figure 4.23).

Short term water deficit may be resulted at certain plant growth stages in flowering and grain-filling stage of maize plant grown with furrow irrigation. It may cause decreased yield and water productivity. Çakir (2004) reported that water stress during the grain filling stage produced the lowest biological and commercial yields compared to other water stress during vegetative growth and flowering stage. El-Mowelhi, Abd El-Hafez, El-Sabbagh and Abou-Ahmed (1999) found that furrow irrigation reduced water productivity as compared with drip irrigation.

4.2.2.6 Harvest index (HI)

Although harvest indices of the tested maize varieties were not significantly different between irrigation methods, it was significantly different among the five tested varieties (Table 4.6). Among the varieties, the variety NK - 621 produced HI of 0.18 which was significantly higher than the other four varieties in which their HI were not significantly different with each other. There was no significant interaction between irrigation methods and tested varieties. However, the maximum harvest index (0.19) was obtained in variety NK - 621 by drip irrigation, followed by NK - 621 (0.17) by furrow irrigation (Figure 4.24). Harvest index of other varieties were statistically the same with each other regardless of irrigation methods.

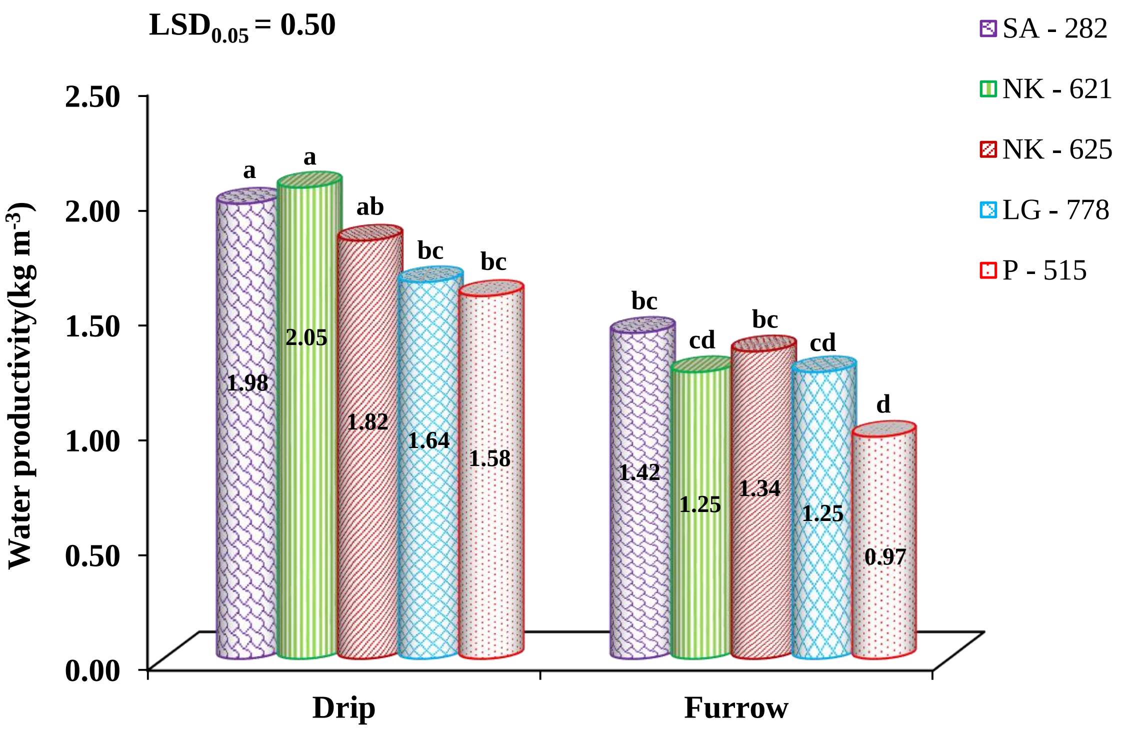


Figure 4.23 Water productivity of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

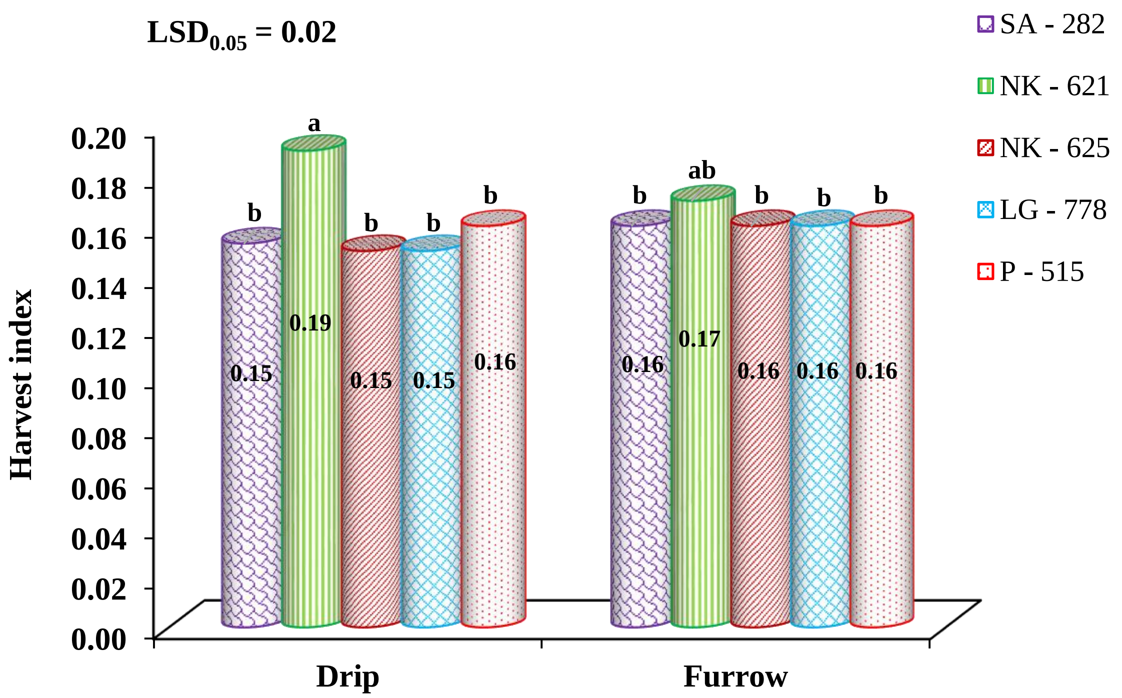


Figure 4.24 Harvest index of maize as affected by two irrigation methods and five varieties in the dry season (November, 2018 to April, 2019)

4.2.3 Correlation between yield and yield components of maize as affected by two different irrigation methods

The correlation analysis between yield and yield components of the tested maize varieties were carried out and the grain yield was significantly and positively correlated with almost all of yield components except number of grains row^{-1}, ear length and number of ear plant^{-1}. Among the correlation coefficient of yield components with grain yield, the values of ear weight and thousand grains weight were superior than other characters. The correlation between ear weight and grain yield was also positive and significant, indicating that increased ear weight could result in increased thousand grains weight and consequently increased grain yield. This result may support the increased grain yield in drip irrigation and variety NK - 621. Khatun, Begum, Motin, Yasmin and Islam (1999); Khazaei, Alikhani, Yari and Khandan (2010) also found that grain yield was significantly and positively correlated with ear weight, thousand gains weight and number of grains ear^{-1}. In this season, shelling percent was positively correlated with ear plant^{-1} and grain yield. This fact supported the highest grain yield of SA - 282 had the more ear plant^{-1} and the higher shelling percent (Table 4.5). However, number of ear plant^{-1} was negatively and significantly correlated with ear length.

In this season, among the yield components, almost all of yield components were significantly and positively correlated with each other except shelling percent and number of ear plant^{-1} as in the first season. However, significant positive association between number of ear plant^{-1} and shelling percent and significant negative association between ear length and number of ear plant^{-1} were observed in this season. Moreover, negative association and not significantly correlated between number of rows ear^{-1} and row length, number of rows ear^{-1} and ear length, and number of grains row^{-1} and number of rows ear^{-1}. There was no significant positive association between number of grains row^{-1} and thousand grains weight, and number of grains row^{-1} and ear diameter were also observed. Haqqani and Pandey (1994) stated that ear length was positively associated with number of grains ear^{-1}, thousand grains weight and grain yield. Devi, Muhammad and Mohammad (2001); Kramer and Boyer. (1995); Mohsan, Singh and Rao (2002) found that number of rows ear^{-1} was significantly correlated with number of grains ear^{-1} and ear diameter.

Table 4.7 Correlation between yield and yield components of maize as affected by two irrigation methods in the dry season (November, 2018 to April, 2019)

	Grain yield	No. of grains row^{-1}	No. of rows ear^{-1}	Row length	No. of grains ear^{-1}	Thousand grains weight	Ear length	Ear diameter	Ear weight	No. of ear $plant^{-1}$
No. of grains row^{-1}	0.26									
No. of rows ear^{-1}	0.52**	-0.05								
Row length	0.37*	0.52**	-0.01							
No. of grains ear^{-1}	0.50**	0.86**	0.46*	0.46*						
Thousand grains weight	0.74**	0.23	0.49**	0.45*	0.46*					
Ear length	0.31	0.60**	-0.03	0.77**	0.52**	0.60**				
Ear diameter	0.68**	0.20	0.70**	0.36*	0.54**	0.89**	0.46*			
Ear weight	0.76**	0.41*	0.48**	0.61**	0.62**	0.95**	0.73**	0.89**		
No. of ear $plant^{-1}$	0.34	-0.19	0.07	-0.29	-0.13	-0.25	-0.51**	-0.28	-0.29	
Shelling percent	0.60**	-0.11	0.28	-0.05	0.05	0.30	-0.16	0.25	0.23	0.44*

* Significant at 5% level, ** Significant at 1% level

4.2.4 Correlation between yield and agronomic characters of maize as affected by two different irrigation methods

The correlation between yield and agronomic characters of the tested maize varieties as shown in (Table 4.8) grain yield was highly and negatively correlated with days to 50% tasseling and days to 50% silking implying that early tasseling and silking date produced higher grain yield. Bello and Olaoye (2009) stated that days to 50% silking was significantly and negatively correlated with grain yield. The early emerged tassels and silks favors early flowering and longer grain filling period. Golam et al. (2011) observed that longer grain filling period produced higher grain yield. In this season, grain yield was highly and positively correlated with plant height. Martin and Russell (1984); Burak and Magoja (1990) also found that grain yield was strongly and positively correlated with plant height.

Days to 50% tasseling was positively and highly correlated with days to 50% silking meaning that if the 50% tasseling date is earlier, 50% silking date will be accordingly earlier. However, days to 50% tasseling was significantly and negatively correlated with plant height and ear height. It indicated that 50% tasseling date was relatively earlier in the plants with increased plant height and ear height. It may lead to longer grain filling period resulting higher grain yield. Ear height was significantly and positively correlated with plant height. Golam et al. (2011) observed that days to 50% tasseling was highly and positively correlated with days to 50% silking. Hasen (1975); Salama, Gada and Sadek (1994) reported that ear height was positively correlated with plant height.

4.3 Gross Margin Analysis

A breakdown of cost/gross margin analysis was provided based on the experiment (Table 4.9 and Table 4.10). For the first season, the revenue of drip irrigation was higher than that of furrow irrigation. However, total variable cost of drip irrigation was higher than that in furrow irrigation because of the initial cost for drip set installation resulting more minus gross margin in drip irrigation. In the second season, although total revenue from drip irrigation (4,599,451.25 MMK) was about 45% higher than that of furrow irrigation (3,157,627.20 MMK), gross margin in drip irrigation was two times greater than that in furrow irrigation. In this season, cost of drip set installation was not calculated and drip pipe set can be used more than at least one time depending on the useful handling.

Table 4.8 Correlation between yield and agronomic characters of maize as affected by two irrigation methods in the dry season (November, 2018 to April, 2019)

	Grain yield	Days to 50% tasseling	Days to 50% silking	Ear height
Days to 50% tasseling	-0.79**			
Days to 50% silking	-0.82**	0.94**		
Ear height	0.33	-0.48**	-0.40*	
Plant height	0.61**	-0.62**	-0.57**	0.72**

* Significant at 5% level, ** Significant at 1% level

Table 4.9 Gross margin analysis for drip and furrow irrigation in maize production (November, 2017 to April, 2018)

	Items	Drip irrigation	Furrow irrigation
		Value	Value
A	**Revenue (Kyats ha^{-1})**		
1	Total Output (kg ha^{-1})	5759.60	4218.60
2	Unit price per kg	361.45	361.45
3	Total Revenue (1x2)	2,081,807.42	1,524,812.97
B	**Total Variable Cost (Kyats ha^{-1})**		
4	Cost of land preparation	111,150.00	111,150.00
5	Cost of fertilizer application	808,480.00	808,480.00
6	Cost of irrigation	1,867,126.00	1,169,351.00
7	Cost of harvesting	118,560.00	118,560.00
8	Total Variable cost (4+5+6+7)	2,905,316.40	2,207,541.40
C	**Gross Margin (Kyats ha^{-1}) (3-8)**	- 823,508.98	- 682,728.43

Table 4.10 Gross margin analysis for drip and furrow irrigation in maize production (November, 2018 to April, 2019)

	Items	Drip irrigation	Furrow irrigation
		Value	Value
A	**Revenue (Kyats ha^{-1})**		
1	Total Output (kg ha^{-1})	12725.00	8736.00
2	Unit price per kg	361.45	361.45
3	Total Revenue (1x2)	4,599,451.25	3,157,627.20
B	**Total Variable Cost (Kyats ha^{-1})**		
4	Cost of land preparation	111150.00	111150.00
5	Cost of fertilizer application	1270568.00	1270568.00
6	Cost of irrigation	785460.00	602680.00
7	Cost of harvesting	138320.00	138320.00
8	Total Variable cost (4+5+6+7)	2,305,498.00	2,122,718.00
C	**Gross Margin (Kyats ha^{-1}) (3-8)**	2,293,953.25	1,034,909.20

CHAPTER V

CONCLUSION

Drip irrigation gave higher grain yield in both dry seasons probably due to increased ear length in the first season and increased ear length and thousand grain weight in the second season. Short term water deficit may be resulted at certain plant growth stages of maize plant grown with furrow irrigation. Drip irrigation seemed to mitigate or may cause free from water deficit at any stages of the plant leading to increase yield due to better grain filling. The five tested varieties were high yielding varieties. However, among all the varieties, the highest grain yield was observed from the variety NK - 621 probably due to increased thousand grains weight in the first season. In the second season, there were significant differences in all parameters except number of grains ear^{-1} among the varieties, and the variety SA - 282 produced the highest grain yield probably due to increased number of ear $plant^{-1}$ and shelling percent. Ear weight and thousand grains weight are very important yield contributing components because of strong and positive correlation with grain yield in both seasons. The responses of varieties varied with irrigation methods in days to 50% tasseling, days to 50% silking, row length, ear length, ear weight and number of ear $plant^{-1}$ in the second season. Although there was no significant interaction effect of irrigation methods and tested varieties on grain yield in both seasons, the highest grain yield was obtained from the varieties P - 515 and NK - 621 under drip irrigation in first season, and from the varieties NK - 621 and SA - 282 under drip irrigation in the second season. Among the varieties under furrow irrigation in the second season, the highest grain yield was obtained from the variety SA - 282. Therefore the variety SA - 282 is suitable for furrow irrigation if the farmers had no option other than furrow irrigation. Drip irrigation can give more profit than furrow irrigation in dry season for long term in the area with favorable environment for maize production, and ultimately, growing maize by drip irrigation would solve the challenges like water scarcity due to climate change.

REFERENCES

Abbas, G., Hussain, A., Ahmad, A., & Wajid, S. (2005). Effect of irrigation schedules and nitrogen rates on yield and yield components of maize. *Journal of Agriculture and Social Sciences, 1,* 335-338.

Abdelgadir, H.A. (2002). *Response of two maize* (*Zea mays* L.) *varieties to different quantities of irrigation water*. M.Sc. (Agric.) thesis. University of Khartoum, Khartoum, Sudan.

Abrecht, D., & Carberry, P. (1993). The influence of water deficit prior to tassel initiation on maize growth, development and yield. *Field Crops Research, 31*(1-2), 55-69.

Abu Hasbro, N.M. (2002). *Effect of tillage operations and water duties on maize production* (*Zea mays* L.). M.Sc. (Agric.) thesis. University of Khartoum, Khartoum, Sudan.

Adhikary, B. H., Shrestha, J., & Baral, B. R. (2010). Effects of micronutrients on growth and productivity of maize in acidic soil. *International Research Journal of Applied and Basic Sciences, 1*(1), 8-15.

Ahmed, F., & El Hag, H. (1999). Effect of watering intervals on yield and yield components of two maize (*Zea mays* L.) cultivars grown in summer and winter. *University of Khartoum Journal of Agricultural Sciences, 7*(1), 20-32.

Ahmed, F.E. (2002). Water stress and genotype effects on yield and seed quality in maize (*Zea mays* L.). *University of Khartoum Journal of Agricultural Sciences, 10*(2), 213-223.

Akinyele, O., Oladimeji, S., Anjorin, S., Akinola, O., & Oke, A. (2016). Effect of Irrigation Frequency on the Growth of Selected Maize (*Zea mays* L.) Varieties. *International Journal of Innovative Science, Engineering & Technology, 3*(4), 339-407.

Allen, R. G., Wright, J. L., Pruitt, W. O., Pereira, L. S., & Jensen, M. E. (2007). *Water Requirements Design and Operation of Farm Irrigation Systems,* (2nd ed., pp. 208-288): American Society of Agricultural and Biological Engineers.

Ashoub, M., Hassanein, M., Abd-El-Aziz, M., Shahin, M., & Gohar, M. (1996). Influence of irrigation, nitrogen, zinc and manganese fertilization on yield and yield components of maize. *Annals of Agricultural Science, Ain-Shams Universities (Egypt), 41*(2), 697-711.

Ayars, J., Fulton, A., & Taylor, B. (2015). Subsurface drip irrigation in California—Here to stay? *Agricultural water management, 157,* 39-47.

Bamohuni, S. (2011). Design proposal of drip irrigation system for an efficient management of irrigation water for maize improved seeds production in a part of seeds farm of loumbila. *Universita degli Studi di Firenze Facolta di Agraria,* 33-40.

Bänziger, M., Edmeades, G. O., & Lafitte, H. R. (1999). Selection for drought tolerance increases maize yields over a range of N levels. *Crop Science Journal, 39*(4), 1035-1040.

Bänziger, M., Edmeades, G. O., & Lafitte, H. R. (2002). Physiological mechanisms contributing to the increased N stress tolerance of tropical maize selected for drought tolerance. *Field Crops Research, 75*(2-3), 223-233.

Bello, O., Abdulmaliq, S., Afolabi, M., & Ige, S. (2010). Correlation and path coefficient analysis of yield and agronomic characters among open pollinated maize varieties and their F_1 hybrids in a diallel cross. *African Journal of Biotechnology, 9*(18), 2633-2639.

Bello, O.B., & Olaoye, G. (2009). Combining ability for maize grain yield and other agronomic characters in a typical southern guinea savanna ecology of Nigeria. *African Journal of Biotechnology, 8*(11), 2518-2522.

Birch, C., Robertson, M., Humphreys, E., & Hutchins, N. (2003). Agronomy of maize in Australia-in review and prospects. *Versatile Maize-Golden Oppoitunities, 5th ed.; Birch, CJ, Wilson, SR, Eds,* 18-20.

Boutheina, D., & Boujelben, A. (2011). Subsurface drip irrigation and water management under semiarid climate. *Advances in Environmental Research, 22,* 181-198.

Brouwer, C., Prins, K., & Heibloem, M. (1989). Irrigation water management: irrigation scheduling. *Training manual, 4*.

Burak, R., & Magoja, J. (1990). Yield and yield components of full sib and half sib families derived from a perennial teosinte introgressed population. *Maize Genetics Cooperation News Letter* (64), pp. 76.

Burak, R., & Magoja, J.L. (1991). Yield and yield components of full-sib and half-sib families derived from perennial teosinte introgression population. *Maize Genetics Cooperation News Letter, 7,* 431-76.

Cakir, R. (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Field Crops Research, 89*(1), 1-16.

Camp, C. (1998). Subsurface drip irrigation: A review. *Transactions of the ASAE, 41*(5), 1353- 1367.

Cassel, D., Martin, C., & Lambert, J. (1985). Corn Irrigation Scheduling in Humid Regions on Sandy Soils with Tillage Pans 1. *Agronomy Journal, 77*(6), 851-855.

Caswell, M. F. (1991). Irrigation technology adoption decisions: Empirical evidence. *The economics and management of water and drainage in agriculture* (pp. 295-312): Springer, Boston.

Centro Internacional de Mejoramiento de Maíz y Trigo. (1985). Annual report. 1986. CIMMYT, Int. Mexico, DF (Mexico). CIMMYT. Series: CIMMYT Annual Report. 74p.

Chaudhary, A. (1983). Maize in Pakistan, Punjab Agri. *Research Coordination Board University of Agriculture.* Faisalabad, Pakistan. 111p.

Claasen, M., & Shaw, R. (1970). Water deficit effects on corn. II. Grain components. *Agronomy Journal, 62,* 652-655.

Cook, S., Gichuki, F., & Turral, H. (2006). Water productivity: Estimation at plot, farm and basin scale. *People and Agro-Ecosystems Research for Development Challenge; Centro Internacional de Agricultura Tropical: Cali, Colombia*, p. 144.

Darouich, H. M., Pedras, C. M., Goncalves, J. M., & Pereira, L. S. (2014). Drip vs. surface irrigation: A comparison focusing on water saving and economic returns using multi-criteria analysis applied to cotton. *Bio-systems engineering, 122,* 74-90.

Degirmenci, V., Gunduz, M., & Kara, C. (1998). Water–yield Relationship of Second Crop Corn in Harran Plain in the GAP region. *Rural Services Sanliurfa Research Institute Publications*, *Sanliurfa, Turkey*, pp. 45.

Denmead, O., & Shaw, R. H. (1960). The Effects of Soil Moisture Stress at Different Stages of Growth on the Development and Yield of Corn 1. *Agronomy Journal, 52*(5), 272-274.

Devi, I. S., Muhammad, S., & Mohammad, S. (2001). Character association and path coefficient analysis of grain yield and yield components in double cross of maize (*Zea mays* L.). *Crop Research Hisar, 21*(3), 335-359.

Dhillon, B., Thind, H., Saxena, V., Sharma, R., & Malhi, N. (1995). Tolerance to excess water stress and its association with other traits in maize. *Crop Improvement, 22*(1), 22-28.

Dogan, E., & Kirnak, H. (2010). Water temperature and system pressure effect on drip lateral properties. *Irrigation Science, 28*(5), 407-419.

Donald, C. M. (1962). In search of yield. *The Journal of the Australian Institute of Agricultural Science, 28,* 171-178.

Du Plessis, J. (2003). *Maize production*: Department of Agriculture Pretoria, South Africa. pp. 1-38.

Edmeades, G., Bolaños, J., & Lafitte, H. (1990). *Selection for drought tolerance in maize adapted to the lowland tropics.* Paper presented at the 4. Asian Regional Maize Workshop, Islamabad (Pakistan), 21-28.

El-Hendawy, S., Hokam, E., & Schmidhalter, U. (2008). Drip irrigation frequency: the effects and their interaction with nitrogen fertilization on sandy soil water distribution, maize yield and water use efficiency under Egyptian conditions. *Journal of Agronomy and Crop Science, 194*(3), 180-192.

El-Mowelhi, N. M., Abd El-Hafez, S. A, El-Sabbagh, A. A., & Abou- Ahmed, E. I. (1999). *Evaluation of drip irrigated maize in North Delta*, Egypt. 3rd Conference of on farm irrigation and agroclimatology, (1), 223-231.

El-Shenawy, A. (1990). *Effect of water stress and plant population on single and double crosses of maize*, (*Zea mays* L.), Egypt. 135p.

El-Wahed, M. A., & Ali, E. (2013). Effect of irrigation systems, amounts of irrigation water and mulching on corn yield, water use efficiency and net profit. *Agricultural water management, 120,* 64-71.

Elzubeir, A.O., & Mohamed, A.E. (2011). Irrigation scheduling for maize (*Zea mays* L.) under desert area conditions-North of Sudan. *Agriculture and Biology Journal of North America, 2*(4), 645-651.

Farnham, D., Benson, G., & Pearce, R. (2003). Corn Perspective and Culture. Corn Chemistry and Technology, PJ White and LA Johnson editors: AACC Press. 369p.

Filintas, A., Dioudis, P., Hatzopoulos, J., & Karantounias, G. (2008). *Irrigation effects in Maize yield, plant stress and GIS integrated modelling of available soil moisture.* Paper presented at the Proceedings of International Conference: Studying, Modeling and Sense Making of Planet Earth, Greece, April.

Food and Agriculture Organization. (1984). Localized irrigation. *FAO irrigation and drainage paper NO 36.* Prepared by Vermeiren, L. & Jobling, G. A.

Food and Agriculture Organization. (1996). *Irrigation Scheduling from Theory to Practice.* Water Reports 8. 384.

Food and Agriculture Organization. (2001). Irrigation Manual. *Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation,* Volume III, Module 8.

Food and Agriculture Organization. (2011). *Corporate Document Repository*, Chapter 3.

Food and Agriculture Organization. (2016). *Irrigation areas, irrigated crops, environment.*

Ge, T., Sui, F., Bai, L., Tong, C., & Sun, N. (2012). Effects of water stress on growth, biomass partitioning, and water-use efficiency in summer maize (*Zea mays* L.) throughout the growth cycle. *Acta Physiologiae Plantarum*, *34*(3), 1043-1053.

GEOFIN. (2016). *GEOFIN Maize Special Report*. Geofin Comtrade Ltd. Geofin Research Desk, Kochi-682 024, Kerala. Retrieved from http://www.geofin.co.in/ Research Rept/Maize _Special_Report_June_2016

Gleick, P. H. (1998). *The world's water 1998-1999: the biennial report on freshwater resources*: Island Press. 232p.

Global Agricultural Information Network. (2018). *Burma- Union of Grain and Feed Annual Report*. Report Number: BM 8003

Golam, F., Farhana, N., Zain, M. F., Majid, N. A., Rahman, M., Rahman, M. M., & Kadir, M. A. (2011). Grain yield and associated traits of maize (*Zea mays* L.) genotypes in Malaysian tropical environment. *African journal of agricultural research, 6*(28), 6147-6154.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*: John Wiley & Sons. 704p.

Gomma, M. (1981). Effect of plant population, nitrogen levels and water stress on two maize cultivars. *Annals Agriculture Science, Moshtohor, 23*(2), 233-330.

Gordon, W., Raney, R., & Stone, L. (1995). Irrigation management practices for corn production in north central Kansas. *Journal of soil and water conservation, 50*(4), 395-399.

Hall, A. J., Lemcoff, J. H., & Trapani, N. (1971). Water stress before and during flowering in maize and its effects on yield, its components, and their determinants. *Maydica (Italy), 26*(1), 19-38.

Hall, A., Vilella, F., Trapani, N., & Chimenti, C. (1982). The effects of water stress and genotype on the dynamics of pollen-shedding and silking in maize. *Field Crops Research, 5,* 349-363.

Hansen, L. A. (1975). *The inheritance of ten quantitative characteristics in sweet corn* (*Zea mays* L.). Ph.D. (Horticulture) thesis. Oregon State University, Oregon, Corvallis.

Hansen, V. E., Israelsen, O. W., & Stringham, G. E. (1980). Irrigation principles and practices. *John Wiley& Sons, New York*. 238p.

Haqqani, A., & Pandey, R. (1994). Response of mung bean to water stress and irrigation at various growth stages and plant densities. I. Plant and crop growth parameters. *Tropical agriculture, 71*(4), 281-288.

Haqqani, A., & Pandey, R. (1994). Response of mung bean to water stress and irrigation at various growth stages and plant densities: II. Yield and yield components. *Tropical agriculture*, *71*(4), 289-294.

Harris, D., Rashid, A., Miraj, G., Arif, M., & Shah, H. (2007). 'On-farm'seed priming with zinc sulphate solution—A cost-effective way to increase the maize yields of resource-poor farmers. *Field Crops Research, 102*(2), 119-127.

Herbst, S. T., & Herbst, R. (2007). *new food lover's companion*: Barron's Educational Series, Inc. ISBN 0764112589

Hernadez, T. (1980). Influence of soil moisture content at different growth stages on yield of maize in the state of Morelos. *Field crop abstract, 36*(3), 2240.

Herrero, M. P., & Johnson, R. (1981). Drought stress and its effects on maize reproductive systems 1. *Crop science*, *21*(1), 105-110.

Heuzé, V., Tran, G., Sauvant, D., & Lebas, F. (2017). *Brewers grains*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. Retrieved from https://www. feedipedia .org/node/74

Huang, R., Birch, C., & George, D. (2006). *Water Use efficiency in maize production the challenge and improvement strategies.* Paper presented at the Proceeding of 6th Triennial Conference, Maize Association of Australia, February.

Hussaini, M., Ogunlela, V., Ramalan, A., & Falaki, A. (2008). Mineral composition of dry season maize (Zea mays L.) in response to varying levels of nitrogen, phosphorus and irrigation at Kadawa, Nigeria. *World Journal of Agricultural Sciences*, *4*(6), 775-780.

Ibragimov, N., Evett, S. R., Esanbekov, Y., Kamilov, B. S., Mirzaev, L., & Lamers, J. P. (2007). Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation. *Agricultural water management, 90*(1-2), 112-120.

Igbadun, H. E., Mahoo, H. F., Tarimo, A., & Salim, B. A. (2005). *Productivity of water and economic benefit associated with deficit irrigation scheduling in maize.* Paper presented at the Proceedings of the East Africa Integrated River Basin Management Conference. Morogoro, Tanzania, March.

International Institute of Tropical Agriculture. (2012). *Research to Nourish Africa, Research for Development, Maize.* Retrieved from https://www.iita.org/cropsnew /maize/

Irmak, S., Djaman, K., & Rudnick, D. R. (2016). Effect of full and limited irrigation amount and frequency on subsurface drip-irrigated maize evapotranspiration, yield, water use efficiency and yield response factors. *Irrigation Science, 34*(4), 271-286.

Jensen, M., Rangeley, W., & Dieleman, P. (1990). Irrigation trends in world agriculture. *Agronomy* (30), 31-67.

Kang, Y., Wang, F. X., & Liu, S. P. (2002). *Effects of drip irrigation frequency on soil wetting pattern and root distribution of potato in North China Plain.* Paper presented at the 2002 ASAE Annual Meeting, Chicago, July 28-31.

Kara, T., & Biber, C. (2008). Irrigation frequencies and corn (*Zea mays* L.) yield relation in Northern Turkey. *Pakistan Journal of Biological Sciences, 11,* 123-126.

Karasu, A., Kuscu, H., & Öz, M. (2015). Yield and economic return response of silage maize to different levels of irrigation water in a sub-humid zone. *Zemdirbyste-Agriculture*, *102*(3), 313-318.

Kefale, D., & Ranamukhaarachchi, S. (2004). Response of maize varieties to drought stress at different phenological stages in Ethiopia. *Tropical science, 44*(2), 61-66.

Khan, M. B., Hussain, N., & Iqbal, M. (2001). Effect of water stress on growth and yield components of maize variety YHS 202. *Journal of Research Science, 12*(1), 15-18.

Khan, M., Asif, M., & Aman, M. (2003). Response of some maize (*Zea mays* L.) genotypes to different irrigation levels. *International Journal Agriculture Biological, 5*(1), 17-18.

Khatun, F., Begum, S., Motin, A., Yasmin, S., & Islam, M. (1999). Correlation coefficient and path analysis of some maize (*Zea mays* L.) hybrids. *Bangladesh Journal of Botany, 28*(1), 9-15.

Khazaei, F., Alikhani, M. A., Yari, L., & Khandan, A. (2010). Study the correlation, regression and path coefficient analysis in sweet corn (*Zea mays* var. saccharata*)* under different levels of plant density and nitrogen rate. *Journal of Agricultural and Biological Science, 5*(6), 14-19.

Khedr, E., Matta, S., Wahba, M., & El-Koliey, M. (1996). Effect of water regime on yield of some maize cultivars and water relations. *Bulletin of Faculty of Agriculture, Cairo Universities (Egypt)*, *41*(1), 87-98.

Khodarahmpour, Z. (2012). Morphological classification of maize (*Zea mays* L.) genotypes in heat stress condition. *Journal of Agricultural Science, 4*(5), 31.

Kramer, P. J., & Boyer, J. S. (1995). *Water relations of plants and soils*: Academic Press. 495p.

Kuşçu, H., & Demir, A. O. (2012). Responses of maize to full and limited irrigation at different plant growth stages. *Uludağ Üniversitesi Ziraat Fakültesi Dergisi, 26*(2), 15-28.

Lee, H., Jauh, S. F., Long, T. W., & Shung, L. H. (2001). Studies on the agronomic traits and forage maize hybrids. *Journal of Agricultural Research China, 50,* 25-32.

Malik, H., Malik, S. I., Hussain, M., Chughtai, S., & Javed, H. I. (2005). Genetic correlation among various quantitative characters in maize (*Zea mays* L.) hybrids. *Journal of Agriculture & Social Sciences, 3*, 262-265.

Malvar, R.A., Revilla, P., & Ordas, A. (1994). *Additive correlation between days to flowering and agronomic traits in low land races of maize.* Paper presented at the Anales de la Estación Experimental de Aula Dei, 20, 59-64.

Martin, M., & Russell, W. (1984). Correlated Responses of Yield and Other Agronomic Traits to Recurrent Selection for Stalk Quality in a Maize Synthetic 1. *Crop science, 24*(4), 746-750.

Mayhew, S., & Penny, A. (1988). *Macmillan Tropical and Sub-Tropical Foods*: Macmillan Publishers Ltd. 291p.

Mcpherson, H. G., & Boyer, J. S. (1977). Regulation of grain yield by photosynthesis in maize subjected to a water deficiency. *Agronomy Journal, 69*(4), 714-718.

Michael, A. (2008). Irrigation theory and practice, (revised and enlarged) Vikas Publishing House *Private Limited, Delhi, India.* 768p.

Ministry of Agriculture and Irrigation. (2014). *Myanmar Agriculture in Brief*. Ministry of Agriculture and Irrigation. Nay Pyi Taw, Myanmar.

Ministry of Agriculture, Livestock and Irrigation. (2018). *Myanmar Agriculture in Brief.* Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar.

Mohammadi, S., & Prasanna, B. (2003). Analysis of genetic diversity in crop plants-salient statistical tools and considerations. *Crop science, 43*(4), 1235-1248.

Mohsan, Y., Singh, D., & Rao, N. (2002). Path coefficient analysis for oil and grain yield in maize (Zea mays L.) genotypes. *National Journal Plant Improvement, 4*(1), 75-77.

Molnár, S. k. (1977). *öntözéses kukoricatermelés gazdaságossági kérdései*: Akadémiai Kiadó. ISBN : 9630513390

Nafziger, E. (2010). Growth and production of maize: mechanized cultivation. *Soils, Plant Growth and Crop Production-Volume I*, 331.

Namara, R., Upadhyay, B., & Nagar, R. K. (2005). *Adoption and impacts of micro-irrigation technologies: Empirical results from selected localities of Maharashtra and Gujarat States of India.* Research report 93. Colombo, Sri Lanka: International Water Management Institute (IWMI).

National Agro-Technical Extension Service Centre. (2003). Corn Cultivation Technology Training Course. National Agro-Technical Extension Service Centre, China. Retrieved from https://www.google.com/search?sa=X&biw=1054&bih=600&sxsrf=ACYBGNQAGjYMD1-VgggoryTLeu_uPW5caw:1572983471453&q=NATESC+(2003)+stated+that+unreasonable+irrigation+will+lead+to+a+low+yield+although+input+is+high.+While+reasonable+irrigation+gives+the+crop+a+proper+water+supply,+which+will+not+only+satisfy+the+need+for+normal+growth+but+also+avoid+water+losses.&tbm=isch&source=lnms&ved=2ahUKEwjosraI7NPlAhVBs48KHcD7DlYQ7Al6BAgDECQ

O'Gara, F. F. P. (2007). *Irrigated maize production in the top end of the Northern Territory*. Northern Territory Government, Department of Primary Industry, Fisheries and Mines, 2007. Retrieved from http://www.nt.gov.au/dpifm/content/file/p/Tech_Bull/ TB326.pdf

Oktem, A. (2008). Effects of deficit irrigation on some yield characteristics of sweet corn. *Bangladesh Journal of Botany, 37*(2), 127-131.

Onasanya, R., Aiyelari, O., Onasanya, A., Oikeh, S., Nwilene, F., & Oyelakin, O. (2009). Growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizers in southern Nigeria. *World Journal of Agricultural Sciences, 5*(4), 400-407.

Pandey, A., Ved, P., Mani, V., & Singh, R. (2000). Effect of rate of nitrogen and time of application on yield and economics of babycorn (*Zea mays* L.). *Indian Journal of Agronomy, 45*(2), 338-343.

Pandey, R., Maranville, J., & Admou, A. (2000). Deficit irrigation and nitrogen effects on maize in Sahelian environment. I. Grain yield and yield components. *Agricultural water management, 46*(1), 1-13.

Pandey, R., Maranville, J., & Chetima, M. (2000). Deficit irrigation and nitrogen effects on maize in a Sahelian environment: II. Shoot growth, nitrogen uptake and water extraction. *Agricultural water management, 46*(1), 15-27.

Park, R. D. & Eddowes, M. (1975). *Crop Husbandry*. 2nd edition. Oxford University Press. 323 p.

Patel, J., Patel, V., & Patel, J. (2006). Influence of different methods of irrigation and nitrogen levels on crop growth rate and yield of maize (*Zea mays* L.). *Indian Journal of Crop Science, 1*(1-2), 175-177.

Payero, J. O., Melvin, S. R., Irmak, S., & Tarkalson, D. (2006). Yield response of corn to deficit irrigation in a semiarid climate. *Agricultural water management, 84*(1-2), 101-112.

Payero, J. O., Tarkalson, D. D., Irmak, S., Davison, D., & Petersen, J. L. (2009). Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency and dry mass. *Agricultural water management, 96*(10), 1387-1397.

Pereira, L., Feddes, R., Gilley, J., & Lesaffre, B. (2013). *Sustainability of irrigated agriculture* (Vol. 312): Springer Science & Business Media. 602p.

Pervez, H. Z., Srinivasan, G., Cordova, H. S., & Sanchez, C. (2004). Grains from improvement for mid-season drought to tolerance in tropical maize (*Zea mays* L.). *Field Crop Research, 89,* 135-152.

Phene, C., & Beale, O. (1976). High-frequency irrigation for water nutrient management in humid regions 1. *Soil Science Society of America Journal, 40*(3), 430-436.

Pierre, W.H.; Aldrich, S.R. & Martin, W.P. (1972). *Advance in Corn Production: Principles and Practices*. Ames: Iowa State University Press. 476p.

Population Reference Bureau. (2014). *2014 world population data sheet*: PRB Washington, DC. Retrieved from https://www.prb.org/2014-world-population-data-sheet

Population Reference Bureau. (2018). *2018 world population data sheet*: PRB Washington, DC. Retrieved from https://www.prb.org/2018-world-population-data- sheet-with-focus- on hanging-age-structures

Porro, I., & Cassel, D. (1986). Response of Corn to Tillage and Delayed Irrigation 1. *Agronomy Journal, 78*(4), 688-693.

Postel, S. (1999). *Pillar of sand: can the irrigation miracle last?* : WW Norton & Company. 313p.

Prasai, H. K., Sharma, S., Kushwaha, U. K. S., & Shrestha, J. (2015). Evaluation of Quality Protein Maize and Drought Tolerant Maize in Far Western Hills of Nepal. *International Journal of Applied Sciences and Biotechnology, 3*(3), 387-391.

Reddy, S. R. (2006). *Agronomy of field crops*. 2nd Ed. (Kalyani Publishers New Delhi India), pp. 209.

Rhoads, F., & Yonts, C. (2000). Irrigation Scheduling for Corn–Why and How. National Corn Handbook. *Water Management (Irrigation). US Department of Agriculture (USDA).* Retrieved from http://corn.agronomy.wisc.edu/Management/pdfs/NCH20.pdf

Ritchie, S., Hanway, J., & Benson, G. (1993). How a corn plant develops. Iowa State Univ. *Coop. extension service Spec. Rep, 48*, 21.

Robins, J., & Domingo, C. (1953). Some effects of severe soil moisture deficits at specific growth stages in corn 1. *Agronomy Journal, 45*(12), 618-621.

Salama, F., Gado, H., Goda, A. S., & Sadek, S. (1994). Correlation and path coefficient analysis in eight white maize (Zea mays L) hybrid characters. *Menofiya Journal of Agricultural Research, 19,* 3009-3020.

Shaw, R. H. (1988). Climate requirement. *Corn and corn improvement* (cornandcornimpr), 609-638.

Singh, A., Roy, A., & Kaur, D. (2007). Effect of irrigation and NPK on nutrient uptake pattern and qualitative parameter in winter maize + potato intercropping system. *International Journal Agriculture Science, 3*(1), 199-201.

Singha, N., & Prodhan, S.H. (2000). Character association in green maize. *Environment and Ecology*, *18*(4), 962-925.

Szőke, C. (2015). Inheritance of Plant and Ear Height in Maize (*Zea Mays* L.). *Agricultural Research Institute of the Hungarian Academy of Sciences, Martonvásár.* Retrieved from https://www.researchgate.net/publication/267955749

Tibaquirá, J., Huertas, J., Ospina, S., Quirama, L., & Niño, J. (2018). The effect of using ethanol-gasoline blends on the mechanical, energy and environmental performance of in-use vehicles. *Energies, 11*(1), 221.

Traore, S. B., Carlson, R. E., Pilcher, C. D., & Rice, M. E. (2000). Bt and non-Bt maize growth and development as affected by temperature and drought stress. *Agronomy Journal*, *92*(5), 1027-1035.

Usoh, G., Nwa, E., Okokon, F., Nta, S., & Etim, P. (2017). Effects of Drip and Furrow Irrigation Systems Application on Growth Characteristics and Yield of Sweet Maize under Sandy Loam Soil. *International Journal of Scientific Engineering and Science, 1*(1), 22-25.

Walker, W. (2003). SIRMOD III-Surface Irrigation Simulation, Evaluation and Design (Guide and Technical Documentation). *Logan, Utah State University. 130p*.

Walker, W. R., & Skogerboe, G. V. (1987). *Surface irrigation. Theory and practice*: Prentice-Hall. Englewood Cliffs, New Jersey, USA.

Wallace, H. A., & Bressman, E. N. (1937). *Corn and corn growing.* John Wiley & Sons, New York. 431p.

Westgate, M. E. (1994). Water status and development of the maize endosperm and embryo during drought. *Crop science, 34*(1), 76-83.

Westgate, M. E., & Boyer, J. S. (1986). Reproduction at Low and Pollen Water Potentials in Maize 1. *Crop science, 26*(5), 951-956.

World Bank. (2003). *World Development Report 2004 (Overview): Making Services Work for Poor People*. World Bank.

Yaghi, T., Arslan, A., & Naoum, F. (2013). Cucumber (*Cucumis sativus,* L.) water use efficiency (WUE) under plastic mulch and drip irrigation. *Agricultural water management, 128,* 149-157.

Yang, C. M., & Hsiang, W. M. (1994). Growth and yield of rice as affected by soil water deficits. *Chinese Journal Agromet,* (4), 143-150.

Yang, C.M., Fan, M.J., & Hsiang, W.M. (1994). Growth and Yield Responses of Maize to Soil Water Deficits. *Field Crops Abstract, 47*(1), 167.

Yazar, A., Howell, T., Dusek, D., & Copeland, K. (1999). Evaluation of crop water stress index for LEPA irrigated corn. *Irrigation Science*, *18*(4), 171-180.

Yazar, A., Sezen, S. M., & Gencel, B. (2002). Drip irrigation of corn in the Southeast Anatolia Project (GAP) area in Turkey. *Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage, 51*(4), 293-300.

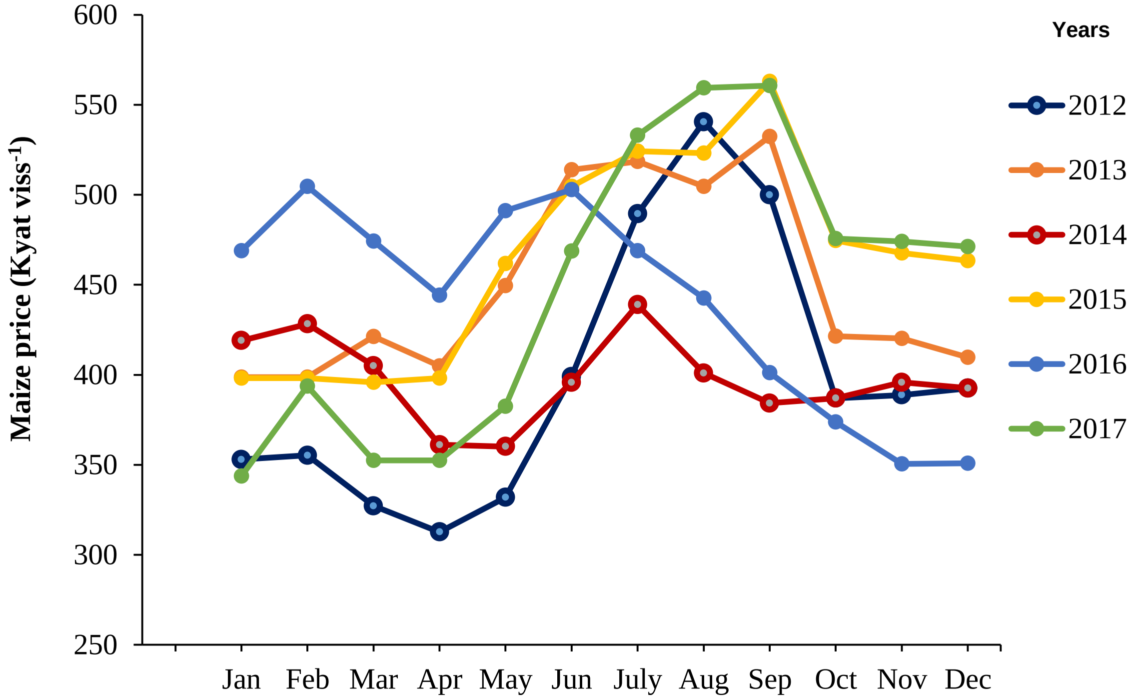
Yazar, A., Sezen S. M., & Gencel, B. (2012). Drip irrigation of corn in the Southeast Anatolia Project (GAP) area in Turkey. *Irrigation and Drainage*, *51*, 293-300.

Yildirim, O., & Korukcu, A. (2000). Comparison of Drip, Sprinkler and Surface Irrigation Systems in Orchards. *Faculty of Agriculture, University of Ankara, Ankara Turkey.* 47p.

You, L., Dong, J., Gu, Y., Ma, L., & Zhao, S. (1998). Target characteristics for improved seed production in maize hybrids. *Journal of Henan Agricultural Sciences, 10,* 3-4.

APPENDICES

Appendix 1 Monthly price of maize during 2012 to 2017



Source: Department of Planning, DOP, 2018

Appendix 2 Physicochemical properties of the soil samples before the experiment in 2017 - 2018 and 2018 - 2019

Characteristics	2017-2018		2018-2019	
	Values	Rating	Values	Rating
Soil pH	8.06	Moderately Alkaline	6.21	Slightly acid
Bulk density	1.9 g cm^3		1.5 g cm^3	
EC	0.27 ms/cm	Low	0.08 ms/cm	Very low
Organic Carbon	0.310 %	Very low	1.049 %	Low
Fe	27.58 ppm	-	28.84 ppm	-
Total N	0.03 %	Very low	0.14 %	Low
Exchangeable Cation mg/100g				
Ca^{++}	13.071	Medium	7.095	
Mg^{++}	2.001	Low	1.015	
Na^{+}	1.7	High	0.837	
K^{+}	0.856	High	0.273	
Available Nutrients				
K_2O	40.2 mg/100g	High	12.8 mg/100g	Medium
P	74.628 ppm	Very high	28.24 ppm	Medium
Soil Texture	84.92% ,4.92% ,10.16%	Sand, silt , clay	78.28% ,11.36% ,9.36%	Sand, silt , clay

Source: Soil and Water Utilization Division, Department of Agriculture, Taunggyi

Appendix 3 SAPA guideline for fertilizer application in 2017 - 2018 and 2018 - 2019

Application date	Fertilizer name	2017-2018		2018-2019	
		Nutrient content	Fertilizer Amount (kg ha^{-1})	Nutrient content	Fertilizer Amount (kg ha^{-1})
Basal application	Cow dung	-	4940	-	4940
	Urea	N_2 (46%)	124	N_2 (46%)	124
	T-super	P_2O_5 (46%)	124	P_2O_5 (46%)	124
	Potash	K_2O (61%)	124	K_2O (61%)	124
After 20 days (V6)	Urea	N_2 (46%)	49	N_2 (46%)	74
	Calcium Nitrate	N (15%), Ca (19%)	148	N (15%), Ca (19%)	111
	Magnesium Sulphate	Mg (10%), S (13%)	99	Mg (10%), S (13%)	111
After 40 days (V12)	Urea	N_2 (46%)	42	N_2 (46%)	49
	AWBA korn-Kali +B	K_2O (40%), Mg (4%), S (4%)	25	K_2O (40%), Mg (4%), S (4%)	62
After 60 days (VT)	Urea	N_2 (46%)	25	N_2 (46%)	37
	AWBA korn Kerli+B	K_2O (40%), Mg (4%), S (4%)	37	K_2O (40%), Mg (4%), S (4%)	49

Appendix 4 Irrigation schedule for the drip irrigation

Sr.	Day after sowing (DAS)	Water requirement for one hectare		Percentage (%)
		mm	L	
1	sowing	13.99	139,906	2
2	4	13.99	139,906	2
3	8	13.99	139,906	2
4	12	13.99	139,906	2
5	16	13.99	139,906	2
6	20	13.99	139,906	2
7	24	13.99	139,906	2
8	28	13.99	139,906	2
9	32	13.99	139,906	2
10	36	13.99	139,906	2
11	40	38.47	384,741	6
12	44	38.47	384,741	6
13	48	38.47	384,741	6
14	52	38.47	384,741	6
15	56	38.47	384,741	6
16	60	38.47	384,741	6
17	64	54.21	542,135	8
18	68	54.21	542,135	8
19	72	54.21	542,135	8
20	76	54.21	542,135	8
21	80	27.98	279,811	4
22	84	27.98	279,811	4
23	88	27.98	279,811	4
24	92	27.98	279,811	4
Total		699.53	6,995,287	100

Appendix 5 Irrigation schedule for the furrow irrigation

Sr.	Day after sowing (DAS)	Water requirement for one hectare		Percentage (%)
		mm	L	
1	Before sowing	112	1,120,000	16
2	25th DAS	140	1,400,000	20
3	50th DAS	231	2,310,000	33
4	75th DAS	217	2,170,000	31
Total		700	7,000,000	100

Appendix 6 Monthly weather data during the experimental periods in 2017 to 2018 at Yezin

Year	Months	Temperature		Rainfall	
		Minimum	Maximum	(mm)	(inches)
2017	November	22.00	33.20	46	1.81
2017	December	17.90	31.30	0	0
2018	January	16.90	30.30	24	0.94
2018	February	16.90	34.40	0	0
2018	March	20.70	37.60	0	0
2018	April	23.60	38.40	26	1.02

Source: Weather station, DAR

Appendix 7 Monthly weather data during the experimental periods in 2018 to 2019 at Yezin

Year	Months	Temperature		Rainfall	
		Minimum	Maximum	(mm)	(inches)
2018	November	20.40	33.00	0	0
2018	December	19.30	31.40	23	0.91
2019	January	25.10	40.20	10	0.39
2019	February	21.00	37.40	0	0
2019	March	17.90	35.40	0	0
2019	April	16.90	31.80	7	0.28

Source: Weather station, DAR

Appendix 8 Plant of five maize varieties under two irrigation methods

SA - 282 with drip irrigation

SA - 282 with furrow irrigation

NK - 621 with drip irrigation

NK - 621 with furrow irrigation

NK - 625 with drip irrigation

NK - 625 with furrow irrigation

LG - 778 with drip irrigation

LG - 778 with furrow irrigation

P - 515 with drip irrigation

P - 515 with furrow irrigation