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Effects of Seedling Type and Age on Yield and Yield-Related Traits of Transplanted Maize (*Zeamays L.)* in Burie District, Northwestern Ethiopia

Habtamu Yigermal[1]; Tilahun Tadesse[2]; Alemu Abate[3], Kelemu Nakachew[4] and Getachew Alemayehu[3]

[1]*Department of Horticulture, Burie Campus, DebreMarkos University, Ethiopia*
[2]*Fogera National Rice Research and Training Center, Ethiopian Institute of Agricultural Research*
[3]*Department of Plant Science, College of Agriculture and Environmental Sciences, Bahir Dar University, Ethiopia;* [4]*Department of Plant Science, College of Agriculture and Natural Resource, DebreMarkos University, Ethiopia; Corresponding E-mail: habtamuyigermal@gmail.com*

አህፅሮት

ይህ የመስክ ሙከራ የተሰራው በቡሬ ወረዳ እንደ ጎርጎሮሲያኑ የዘመን አቆጣጠር 2018 በክረምት ወቅት ሲሆን የዚህ ጥናት ዓላማዎችም የበቆሎን ችግኝ አፍልቶ በማዛመት የዕድገትና የምርት አሰጣጡ ላይ ያለውን ተፅዕኖ ለማየት ነው። ከቅርብ ጊዜ ወዲህ በቡሬ ወረዳ ክረምቱ ቶሎ የመውጣትና ርጥበቱ ቶሎ የመድረቅ በዚህም የተነሳ የበቆሎ ምርት መቀነስ የተለመደ እየሆነ መጥቷል። ይህ ሙከራ የተለያዩ ሁለት የችግኝ አፈላል ዘዴዎች (መደብ እና በፕላስቲክ ላይ) እንዲሁም አምስት (ከ1 እስከ 5 የእውነተኛ ቅጠል) የችግኝ የዕድገት ደረጃን እና የተለመደውን በቀጥታ መዝራት እንደ ማወዳደሪያነት በማካተት ራንደማይዝድ ኮምፕሌት ብሎክ ዲዛይን (RCBD) የሚባል ቴክኒክ በመጠቀም በሶስት ድግግሞሽ ተሰርቷል። በተለያዩ የምርት መለኪያ መንገዶች እና በኢኮኖሚያዊ አዋጭነት መሰረት በቆሎን በፕላስቲክ አፍልቶ ባለ አራት ቅጠል ሲሆን ማዛመት ከሌላው የችግኝ ዓይነት እና የዕድገት ደረጃ ብሎም በቀጥታ ከመዝራት በተሻለ የበቆሎ ምርትን ማሳደግ እንደተቻለ ተረጋግጧል፡፡ ሆኖም ሙከራው ለአንድ ዓመት ብቻ የተሰራ በመሆኑ ድጋሜ ተሰርቶ ልዩነቱን በደንብ ማረጋገጥ ቢቻል ጥሩ ነው።

Abstract

The field experiment was conducted during the main rainy season of 2018 in Burie district to evaluate the effect of types and growth stages of seedlings on yield and yield-related traits of transplanted maize (Zea mays L.). In the District, terminal moisture stress and grain yield loss become the common challenges in maize production. The experiment was conducted in a factorial combinations of two types of seedlings (bare-rooted and polybagged) and five levels of seedling's growth stages (seedlings of 1, 2, 3, 4 and 5 true leaf/ves) pulse one control (direct-seeded). The treatments were laid down in RCBD with three replications. Data on yield and yield-related parameters were collected following standard procedures and subjected to analysis of variance using SAS software; and mean separation for significant treatments was done by LSD. Both main effects affected the number of grains cob^{-1}, grain and stover yield highly significantly. Types of seedlings significantly affected the number of cobs plant^{-1}, cob length, the number of grains row^{-1}, and biomass yield. The number of cobs plant^{-1}, cob length, number of grains row^{-1} and biomass yield was also highly significantly affected by seedlings growth stages. The interaction effect was highly significant on number of cobs plant^{-1}, grain and stover yield and very highly significant on harvest index. The highest (10.7t ha^{-1}) grain yield of maize was found from the transplantation of polybagged seedlings at four leaf stages. This treatment combination also gave the highest net benefit with an acceptable range of marginal rate of return. Therefore, transplanting of polybagged seedlings at four true leaf stages is economically feasible and can be recommended tentatively for Burie District and similar agro-ecologies. However to come up with a concrete recommendation, it is advised to repeat the study in similar agro-ecologies of maize production.

Keywords: Growth stages, maize, net benefit, seedling type, transplanting, yield

Introduction

Agronomic research on maize has largely focused on maximizing grain yield by optimizing plant nutrients and other agronomic practices (Van-Averbeke, 2008). Unlike the traditional sowing practice, transplantation of maize is a recent technique. Transplanting is becoming a common and an alternate strategy to direct seeding that is commonly used to establish crops when conditions are less favorable for direct seeding. Moreover late sowing may lead to delay in germination and reduction in plant growth. Hence, grain yield is reduced as the crop might expose to terminal drought or the advancement of growth might be shorten that could reduce the duration for grain filling resulting in small grain size (Biswas *et al.*, 2009). In such cases, grain yield reduction can be compensated by seedling transplantation.

However, the age of transplant is one of the factors which affect plant growth and grain yield; but it is ignored to be considered by the farmers during transplantation. The optimum seedling age to be used depends on the edaphic and climatic (temperature and moisture) factors, location and cultural practices (Weston, 1988). Hence, knowledge on the optimum age of transplant helped to understand the relationship between the physiological state, survival rates in the field and growth responses of the transplant under various cultural systems and environmental factors (Shukla *et al.*, 2011).

The use of transplants can shorten the growth period in the field and therefore late-maturing and high-yielding cultivars can be made to fit in to the available growing season as dictated by either rainfall or temperature (Dale and Drennan, 1997a). Depending on the age of transplants, the time to harvest maize was reduced by one to three weeks in the USA and 10 to 12 days in France (Waters *et al.*, 1990). Badran (2002) stated that under late planting conditions, transplanting of maize may be a possible alternative to direct sowing.

In Burie District, the onset of rainfall is becoming less predictable and delayed from time to time. As a result, terminal moisture stress and grain yield loss become the common challenges in maize production of the study area. Hence, farmers of the study area were forced to shift their crop cultivation to short period crops. Therefore, transplanting of seedlings may be an important area of study in Burie district for maize cultivation considering the field duration and early plant establishment under Ethiopian conditions. Unfortunately, there was no previous study carried out on transplanting of maize in Ethiopia as well as in the study area. Therefore, the present field experiment was carried out *to evaluate the effect of types and growth stages of seedlings on yield and yield-related traits of transplanted maize* at Burie district or to determine the appropriate type of seedling and seedling growth stage of transplant to increase production and productivities of maize at Burie district.

Materials and Methods

Description of the study area

The experiment was conducted at the farm of Burie Campus of Debre Markos University, West Gojjam Zone of Amhara Region, during the rainy season of 2018 (Figure 2.1). Geographically, the experimental site is situated at 10^{o}42'43"N latitude and 37^{o}4'45"E longitude with an altitude of 2,103 m.a.s.l. The agro-ecology of the district is varying from *Woyna Dega* (midlands) to *Dega* (highland). The average minimum and maximum temperatures of the area are 10^{0}c and 25°C, respectively, and its average annual rainfall is 1800 mm. The soil of the experimental site is characteristically Humic Nito and Eutric Vertisols, relatively clay in texture. According to the result of soil analysis conducted by Amhara Design and Supervision Bureau in 2018, the soil of the study site is non-saline (Ec=0.058dS/m), medium in CEC (21.6 cmol kg^{-1}) and available phosphorus (6.25ppm).While it was low in organic carbon (2.11), total nitrogen (0.16%), and weakly acidic with pH of 5.6 as compared to standards of Landon (1991). Major crops grown in the area are maize, wheat, finger millet, pepper, barley, and teff.

Experimental treatments, design, and procedures

The experiment was conducted in factorial combinations of two types of seedlings (bare-root and polybag) and five levels of seedling growth stages (seedlings of 1, 2, 3, 4, and 5 true leaves) plus one standard check (direct-seeded). The treatments were laid out in randomized complete block design (RCBD) with three replications. The gross plot size was 3.75m x 3m ($11.25m^2$). The spacing between blocks and plots was 1.0 m and 0.5 m, respectively. Experimental treatments were allocated to the experimental plots of each block randomly using lottery method. An improved maize variety called "BH-660 (Bako Hybrid-660)" was used for the study. This variety was released by the Bako Research Centre and has become one of the most successful hybrid varieties in Ethiopia as well as in the Amhara region. It is a three-way cross hybrid and the most prominent variety throughout Ethiopia due to its high productivity (average 7 t ha^{-1}) and coverage.

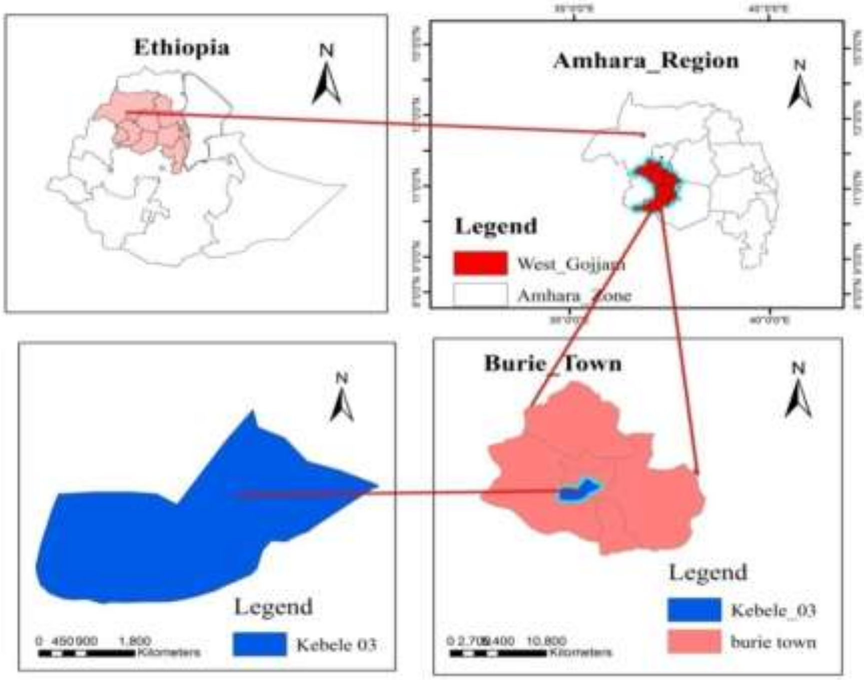

Figure 1. Map of the study area

The seedlings were raised under the nursery through two methods, which are composted and polybag nurseries. The composted nursery was prepared by removing the layer of weeds and stubble above the soil surface; and the soil was plowed, pulverized, and mound. A mixture of sand, compost and topsoil with the proportion of 1:2:3, respectively; and the thick layer of about 10 cm of this growing media were spread all over the bed. The bare root seedlings were raised on one bed which had 1 m width with 10 m length. The maize seeds were sown in line, maintaining a spacing of 20cm x 5cm and cover with a thin layer of pulverized soil. Regarding polybag nursery, the polybags having sizes of 12cm x 8cm were used to raise the seedlings. Each polybag was filled up with a mixture of sand, compost and topsoil with a proportion of 1:2:3, respectively and the polybags were laid on the flat bed by maintaining 1m width; and a single seed was placed in each bag at 1-1.5 cm depth. Proper watering was done when necessary for proper germination and growth of the seedlings.

Sowing at nursery for raising seedlings was done on 22/10/ 2018 and the control was directly sown on one plot in each block on May 27/ 2018 by maintaining a spacing of 75cm x 30cm; and one seed per hill. The seedlings were uprooted carefully with the help of a fork to reduce root injury from the composted nursery. On the other hand, each polybag was turned to remove the plastic from the seedling, while keeping the soil volume intact and the long roots were slashed and transplanting was conducted immediately. Transplanting of one and two true leaf seedlings were done on June 3 and 4 of 2018 respectively, while transplanting of three, four, and five true leaf seedlings were done on June 8, 11, and 19 of 2018, respectively, by maintaining the spacing of 75cm x 30cm and one seedling per hill as the control was done. Thus, there were a total of 5 rows having 10 plants per row and a length of 3m and 50 plants per plot. The net plot size (harvestable area) was 2.25m x 1m ($2.25m^2$) (i.e. the middle 3 rows from each plot) by excluding one outermost row on both sides of each plot vertically and 1m row segment from both ends of the plot horizontally to avoid possible border effects.

Urea (46% N) and Diammonium phosphate (DAP) (18% N and 46% P_2O_5) fertilizers were used as sources of N and P respectively. The full dose of phosphorous and $1/3^{rd}$ of nitrogen fertilizer was applied as band placement at the time of sowing and transplanting for control and seedling transplanting treatments, respectively. The remaining $2/3^{rd}$ of nitrogen fertilizer was applied as top-dressing at knee height of maize following the second hoeing and weeding time. Experimental plots were kept free from weeds by hand weeding as necessary. All other remaining agronomic practices were applied as per their recommendations for maize in the study area. Harvesting was done carefully from the net plot areas by hand on about at 14% moisture content of grains.

Data collection

Some of the data of agronomic parameters of maize were collected as per plot and plant base.

Yield and yield related parameters

Number of cobs per plant: five plants were selected randomly from the net plot and then the total numbers of cobs were counted and the sum was divided by the total number of plants harvested.

Cob length: five cobs were selected randomly from each net plot and measure the length of the cob from the tip to the bottom and the average was taken.

Cob diameter: five cobs were selected randomly from each net plot and measure the circumference of the cob at the center and the diameter was calculated by using the following formula, $d = C/\pi$ where, d= diameter, C= circumference, π= pi.

Number of grain rows per cob: Five cobs were selected randomly from each net plot and grain rows of each cob were counted and the average was taken.

Number of grains per row: Five cobs were collected randomly from each net plot and then numbers of grains in each row of each cob were counted and the average was recorded.

Number of grains per cob: five cobs in each net plot were randomly selected, then numbers of grains in each cob were counted and the average was taken.

Thousands grain weight (g): Two samples of thousand grains were taken at random from each treatment then weighed by digital balance and the average was recorded.

Biomass yield (kg ha^{-1}): The sun-dried total above-ground plant biomass (straw + grain) from the net plot area of each plot at the time of harvesting was measured and the result was converted into a hectare basis.

Grain yield (kg ha^{-1}): The weight of the grains was measured by spring balance from the net plot area of each plot and converted into kilograms per hectare basis after adjusting the grain moisture content to 12.5%.

The grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield (BiruAbebe, 1979).

Stover yield (kg ha^{-1}): Stover yield was determined by deducting the value of grain yield from the value of total above-ground biomass yield.

Harvest index (%): Harvest index of each treatment was calculated as the percent ratio of grain yield to the total above-ground biomass by using the formula of Donald (1962) as;

Data analysis

The data were subjected to statistical analysis SAS (Statistical Analysis Software) version 9.1 to analyze ANOVA. The means were compared by Least Significant Difference (LSD) method at 0.05 probability level. Moreover, correlation analysis was also carried out to study the nature and degree of relationship between yield-related components of maize.

Partial budget analysis

Partial budget analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The gross benefit (GB) was calculated by multiplying yields (the grain yield and stover yield) by corresponding price of each treatment. The sum of cost of poly bag, compost, sand and labour which vary at each treatment was considered as total variable cost. Total variable cost (TVC) (poly bag, compost, sand and labour) for each treatment was calculated and added.

Net benefit (NB) per hectare was calculated by deducting TVC per hectare from GB per hectare. Then, treatments were ranked in order of ascending by total variable cost (TVC) and dominance analysis was done to exclude dominated treatments from further analysis; those treatments costing more but producing a lower net benefit than the next lowest cost treatment are considered to be dominated. Marginal rate of return in percent (MRR %) was calculated by dividing the change in NB to change in TVC and multiplying by 100. MRR was used to ensure acceptable rang of CIMMYT (1988) standard.

Results and Discussion

Number of cobs per plant

The number of cobs per plant was highly significantly ($P<0.01$) influenced by the main effects of both seedling types and seedling growth stages and the interaction of seedlings types and their growth stages. The highest (1.46) number of cobs per plant was recorded from the control, but it was not statistically different from polybagged seedling (1.45). In contrast, transplanting of bare-rooted seedling produce the lowest number of cobs per plant (1.15) (Table 1). This is in agreement with Biswas *et al.* (2009), who reported that the highest number of cobs m^{-2} was recorded in the cup (6.49) and polybag (6.31) nurseries while the lowest was recorded from dry bed nursery (5.87).

Regarding the seedling growth stages, the highest number of cobs per plant were observed from transplanting of four true leaf seedlings (1.47), which was statistically similar ($P>0.01$) with that of control (1.46) treatment. It is followed by transplanting of five true leaf seedlings (1.3) which were at par with transplanting of one and two true leaf seedlings, while the lowest number of cobs per plant was observed from transplanting of three true leaf seedlings (1.17) (Table 1).The result is in agreement with Mrityunjoy (2015), who reported that the highest value for the number of cobs m^{-2} was observed in the direct seeded (6.58) followed by transplanting of 14-day old seedlings (6.42) , while the lowest number of cobs m^{-2} was observed from transplanting of 21-day old seedlings (6.11). Similarly, Biswas (2008) reported that a statistically similar number of cobs m^{-2} was obtained from the direct-seeded (6.216) and transplanting of 14-day old seedlings (6.084). But the results of Biswas revealed that, number of cubs was decreased with the increment of the age of seedling and thus the lowest (5.247) was obtained from the maximum age of seedlings of 42-day old.

The interaction effect of seedling type and growth stages on number of cobs per plant of maize is presented in Table 3.4.The highest number of cobs per plant (1.73) was recorded from the treatments which received transplantation of four true leaf seedlings that grow using polybag, followed by transplantation of two true leaf seedlings that grows in the same manner (1.53). In contrast, the lowest number of cobs per plant (1.07) was recorded from the treatment combination and transplantation of two true leaf seedlings which were grown as bare-rooted seedlings.

Table 1. Yield related parameters of maize as affected by the main effect of types of seedlings and their growth stages

Main effects	NCpP	CL (cm)	CD (cm)
Type of Seedling			
Bare Rooted	1.15b	20.85c	5.17
Poly Bagged	1.45a	24.81a	5.12
Control	1.46a	23.53b	5.03
Growth Stage			
1 True Leaf	1.27bc	21.87bc	5.18
2 True Leaf	1.30b	21.67c	5.18
3 True Leaf	1.17c	21.70bc	5.10
4 True Leaf	1.47a	25.47a	5.13
5 True Leaf	1.30b	23.47b	5.17
control	1.46a	23.53b	5.03
LSD (p<0.05)	**0.1749**	**2.4455**	**0.2844**
CV (%)	7.66	6.44	3.28

NCpP=number of cobs per plant; CL=cob length; CD=cob diameter; CV= coefficient of variation; LSD=least significance difference

Cob length

The cob length of maize was highly significantly (P<0.01) influenced by the main effects of different types of seedlings and growth stages of seedlings but not affected by the interaction of the two factors. The highest (24.81cm) value of cob length was recorded from treatments that received transplanting of polybagged seedlings and followed by the control (23.53), whereas transplanting of bare-rooted seedlings (20.85cm) produce the shortest cobs of maize (Table 1). Furthermore, Fanadzo *et al.* (2009) confirmed that transplanted maize produced longer cobs than direct-seeded maize.

Among the seedling growth stages, the highest cob length was recorded from transplanting of four true leaf seedlings (25.47cm) followed by the control (23.53 cm) and transplanting of five true leaf seedlings (23.47cm) which was also at par with transplanting of one and three true leaf seedlings, while the lowest (21.67) cob length was observed from transplanting of two true leaf seedlings (Table 1). The current result was in agreement with the finding of Biswas (2008) who reported that the highest lengths of cobs were produced in 14- and 21-day old seedlings (16.15cm and 15.82cm) respectively, whereas the lowest (11.20cm) length of cob was recorded in 42-day old seedlings. Similarly, Aihole (2012) reported that the highest cob length was noticed in 12 days old seedlings (21.85 cm) followed by 16 (20.62 cm), 8 (18.63 cm), and 20 days old seedlings (17.26 cm), whereas, the lowest cob length was recorded in the direct sowing (15.03cm). Chudasama *et al.*, (2017) also reported that transplanting of three weeks old seedling recorded significantly maximum (13.30cm) value of cob length, while six weeks old seedling transplanting gives significantly the lowest (9.25cm) cob length of maize.

Cob diameter

The cob diameter of maize was not significantly (p>0.05) affected by types of seedlings, seedlings growth stages, and the interaction of types of seedlings and their growth stages (Table 1).

Number of rows per cob

The number of rows cob^{-1} was not significantly (p>0.05) affected by types of seedlings, seedlings growth stages and their interaction (Table 2).

Table 2. Row number per cob, grain number per row and the cob, and thousand-grain weight of maize as influenced by the main effect of types of seedlings and their growth stages

Main effects	NRpC	NGpR	NGpC	TGW (g)
Type of Seedling				
Bare Rooted	12.33	43.44b	551.74b	455.89
Poly Bagged	12.32	47.19a	581.64a	461.21
Control	12.40	46.40a	565.20ab	452.83
Growth Stage				
1 True Leaf	12.27	44.33bc	545.60c	466.28
2 True Leaf	12.40	44.32bc	544.92c	459.32
3 True Leaf	12.27	44.10c	559.12bc	463.95
4 True Leaf	12.87	47.87a	602.52a	441.72
5 True Leaf	11.84	45.97b	581.30ab	461.50
Control	12.40	46.40ab	565.20bc	452.83
LSD (p<0.05)	**1.1369**	**2.9868**	**51.534**	**36.662**
CV (%)	5.42	3.18	5.00	4.80

NRpC=number of rows cob^{-1}; NGpR=number of grains row^{-1}; NGpC= number of grains cob^{-1}; TGW=thousands grains weight; CV= coefficient of variation; LSD=least significance difference

Number of grains per row

The number of grains row^{-1} was significantly (P<0.001) affected by the main effect of types of seedlings and growth stages of seedlings. However, the interaction of seedling types and growth stages did not significantly (P>0.05) affect the number of grains row^{-1}. The highest number of grains row^{-1} (47.19) were recorded from treatments that received transplanting of polybagged seedlings and it was statistically at parity with the number of grains row^{-1} found from the control (46.40), while transplanting of bare-rooted seedlings (43.44) produce the lowest number of grains row^{-1} (Table 2).

The highest number of grains row^{-1} was recorded from transplanting of four true leaf seedlings (47.87) which was statistically similar (P>0.05) with number of grains row^{-1} noticed in the control (46.40). In contrast, the lowest number of grains row^{-1} were observed from transplanting of three true leaf seedlings (44.10) but it was not statistically different (P>0.05) from that of one and two true leaf seedlings (Table 2). On contrary to this result, Mrityunjoy (2015) reported that the number of grains row^{-1} showed non-significant variations among the age of the seedlings during transplanting. The observation of a higher number of grains row^{-1} from transplanting of poly bagged and four true leaf seedlings might be due to the higher value of cob length from the same transplantation. The correlation analysis also implied that positive and very highly significant correlation of the number of grains row^{-1} was observed with cob length of maize (Table 6).

Number of grains per cob

The number of grains cob^{-1} was affected highly significantly (P<0.01) by both the main effect of seedling types and their growth stages. However, the interaction of types of seedlings and growth stages of seedlings did not affect number of grains cob^{-1} significantly (P>0.05). The highest number of grains cob^{-1} (581.64) of maize was observed from transplanting of polybagged seedlings and it was also statistically similar with number of grains cob^{-1} recorded from the control (565.20), while transplanting of bare-rooted seedlings gave 551.74 numbers of grains cob^{-1} again it was statistically at parity with the value of the control (Table 2). The reason behind this might be due to transplanting seedling from a polybag promote early establishment of transplanted seedlings and/or produce more vigorous seedling with better root system, which leads to higher nutrient use efficiency and finally gave higher number of grains cob^{-1}. In contrast, Kumar *et al.* (2014) reported that significant differences were observed in grains cob^{-1} due to variation in methods of nursery raising as a result significantly higher (292.5) number of grains cob^{-1} was found from raised bed while the lowest (190.4) was noticed from plastic cultured seedlings. Dhillon*et al.* (1990) also found more grains cob^{-1} in raised seedbed than flat seedbed.

Regarding the effect of seedlings growth stages, the highest (602.25) number of grains cob^{-1} were recorded from the transplantation of four true leaf seedlings followed by transplanting of five true leaf seedlings (581.3). While the lowest number of grains cob^{-1} was recorded at transplanting of one (545.60) and two (544.92) true leaf seedlings (Table 2). The correlation analysis also revealed that number of grains cob^{-1} had positive and highly significant correlation with cob length and very highly significant correlation with number of grains row^{-1}(Table 6). In partial agreement with this finding, Aihole (2012) reported that a significantly higher number of seeds cob^{-1} was recorded in 12 days old seedlings (477.41), followed by 16 days old seedlings (472.88) and 8 days old seedlings (434.80), whereas, the lowest number of seeds per cob was noticed in direct sowing (391.71). According to the study of Biswas (2008), the highest (492.89) number of grains cob^{-1} was obtained from 14-day old seedlings due to its higher number of grains row^{-1}. The same author further explained that the number of grains cob^{-1} in direct-seeded (485.33) maize was statistically at par with 14-day old seedlings. But his finding revealed also, the number of grains cob^{-1} was decreased when seedlings age was beyond 14-day and finally the lowest (278.22) number grains $cob^{-1}$was obtained from 42-day old seedlings. Chudasama *et al.* (2017) also reported that three weeks old seedlings recorded significantly maximum (402) number of grains cob^{-1} while six weeks old seedlings produced the lowest (193) number of grains cob^{-1}. In contrast, Olabode *et al.* (2018) reported that there was no significant difference amongst the age of transplanted seedlings concerning the number of seeds cob^{-1} and the number of seeds cob^{-1} ranged between 446-543 seeds.

Thousand-grain weight

Thousand grains weight of maize was not significantly ($p>0.05$) affected by types of seedlings, growth stages of seedlings and their interaction (Table 2).

Biomass yield

The main effects of types and growth stages of seedlings had significant ($P<0.01$) effect on the biomass yield of maize. However, the interaction effect of seedling types and growth stages of seedlings was not significant ($P>0.05$) (Table 3). The highest (29.7 ha^{-1}) biomass yield of maize was found from the direct sown and it was statistically equivalent with the biomass yield recorded from transplantation of polybagged seedlings (28.77t ha^{-1}), while transplanting of bare-rooted seedlings produced the lowest (23.21t ha^{-1}) biomass yield of maize. The reason behind this might be due to transplanting seedling from a polybag promote early establishment of transplanted seedlings and/or produce more vigorous seedling with better root system, which leads to higher growth and finally gave higher biomass. The result of the present finding was in harmony with, Hajong (2017) who reported that the maximum biological yield was recorded with poly bag method of raising seedling and it was significantly superior over flat bed and raised bed seedling raising methods.

The transplanting of four true leaf seedlings gave the highest (31.3 t ha^{-1}) biomass, but was not significantly different ($P>0.05$) from the direct sown maize and transplanting of five true leaf seedlings (29.7 ha^{-1} and 28.6 t ha^{-1}, respectively). However, the lowest (21.98 t ha^{-1}) biomass yield was found from transplanting of one true leaf seedlings and which was also statistically similar ($P>0.05$) with transplantation of two and three true leaf seedlings (Table 3). The correlation analysis also revealed that biomass yield had positively and significantly correlated with number of cobs per plant, cob length, number of grains row^{-1} and number of grains cob^{-1}(Table 6).

In disagreement with the present result, Dereje Assefa *et al.* (2007) reported that results from analysis of variance showed that a significantly higher amount of biomass yield of sorghum was obtained from the transplants of 40 and 30 day old transplants as compared to the direct-sown and the older transplants (50 days). Hajong (2017) reported that in addition to seedlings raising methods, seedlings age also affects the biological yield of transplanted maize. As a result, the maximum biological yield was recorded with one-week old seedling and it was significantly superior over the rest of the treatments, while three week old seedlings produce significantly minimum biological yield. The reason behind this may be due to insufficient time to complete vegetative growth due to early maturity in three week old seedlings.

Table 3.Biomass yield, grain yield, straw yield, and harvest index of maize as affected by the main effect of types of seedlings and their growth stages

Main effects	BMY(t ha^{1})	GY (t ha^{-1})	SY (t ha^{-1})	HI (%)
Type of Seedling				
Bare Rooted	23.21b	6.99b	16.22b	30.01
Poly Bagged	28.77a	8.46a	20.31a	30.41
Control	29.70a	8.60a	20.26a	29.60
Growth Stage				
1 True Leaf	21.98b	6.98c	15.00b	31.75
2 True Leaf	24.10b	7.27c	16.82b	30.23
3 True Leaf	23.99b	7.11c	16.87b	30.27
4 True Leaf	31.30a	9.70a	21.60a	32.42
5 True Leaf	28.60a	7.55bc	21.05a	26.40
Control	29.70a	8.60b	20.26a	29.60
LSD (p<0.05)	**4.694**	**1.4487**	**4.4485**	**6.748**
CV (%)	**11.03**	**11.34**	**14.59**	**13.20**

BMY=biomass yield; GY= grain yield; SY= Stover yield; HI=harvest index; CV= coefficient of variation; LSD=least significance difference

Grain yield

The main and interaction effects of different types of seedlings and growth stages of seedlings had significant (P<0.01) on maize grain yield. The highest grain yield (8.6t ha^{-1}) was noticed from the control treatment of direct seeding and transplanting of polybagged seedlings exhibited statistically equivalent grain yield with the control (8.46t ha^{-1}), while transplanting of bare-rooted seedlings resulted the lowest (6.99 t ha^{-1}) grain yield of maize (Table 3).

The result of Biswas *et al.* (2009) was in partial agreement with the present work which indicated that the highest grain yield was obtained from both the cup (9.3t ha^{-1}) and polybag (9.3t ha^{-1}) nurseries. But the lowest grain yield was obtained from direct planting (8.78t ha^{-1}) which was similar to dry bed (8.81t ha^{-1}) nurseries. In disagreement with the present work Kumar *et al.* (2014) reported that grain yield was significantly affected by the method of seedling raising, and the grain yield obtained through sand cultured plants (5.2t ha^{-1}) was 61% and 10.2%

higher than that of plastic cultured (3.2t ha^{-1}) and flatbed (4.7t ha^{-1}), respectively but it was at par with that of the raised bed (5.1t ha^{-1}).

Transplanting of four true leaf seedlings provided the highest weight of grain yield (9.7t ha^{-1}) which was followed by the grain yield recorded from the control (8.6t ha^{-1}) and it was statistically similar (P>0.05) with grain yield found from transplantation of five true leaf seedlings. In contrast, the lowest weight of grain yield (6.98t ha^{-1}) was recorded from the transplantation of one true leaf seedlings, although it was statistically in parity with grain yield obtained in response to the transplanting of the rest of the treatment (Table 3).The result confirmed that as increasing seedling age up to optimum level results in increasing grain yield. In agreement with this result Biswas (2008) also concluded that, the highest (8.92t ha^{-1}) grain yield was obtained from 14-day old seedlings which was statistically similar to both direct seeded (8.58t ha^{-1}) and 21-day old seedlings (8.79t ha^{-1}). Similarly, Mrityunjoy (2015) reported that the highest (9.59t ha^{-1}) grain yield was found in 14-days old seedlings and direct seeding produced the second highest (9.47t ha^{-1}) grain yield which was statistically similar to 14-days old seedlings, while the lowest (9.25t ha^{-1}) was found in 21-days old seedlings. Kumar *et al.*, (2014) also reported that transplanting of 5 weeks old seedlings produced the highest (5.7t ha^{-1}) grain yield while the lowest (2.7t ha^{-1}) grain yield was obtained from transplantation of 7 weeks old seedlings and it reduced by 36.3, 45.8 and 32.8% from 4 week (4.8t ha^{-1}), 5 and 6 week (4.6t ha^{-1}) age transplantation, respectively. According to the trial of Aihole (2012), significantly the highest (4480.3 kg ha^{-1}) seed yield was recorded from transplanting of 12-days old seedlings compared to direct sowing (3994.8 kg ha^{-1}) and, 8 and 20-days old seedlings recorded (4343.9 and 4319.5 kg ha^{-1}) respectively, which were on par with each other. On the contrary of this findings, Olabode *et al.* (2018) reported that yield of maize was not significantly influenced by age of seedlings at the time of transplanting.

Regarding interaction effect, the highest value of grain yield (10.7t ha^{-1}) was recorded from the treatments which received transplantation of four true leaf seedlings which were grown by polybag, followed by 8.9, 8.7 and 8.6t ha^{-1} of grain yield from the combination of polybagged and two true leaves, bare-rooted and four true leaves and polybagged and five true leaf seedlings, respectively. The control treatment of farmer's practice (direct-seeding) recorded a grain yield of 8.6 t ha^{-1} which was lower than the three best yielding treatments. But the lowest (5.5t ha^{-1}) maize grain yield was recorded from the treatment combination and transplantation of bare rooted and one true leaf seedlings which was also statistically at parity with the combination of bare root and two true leaf seedlings (Table 4).

In partial harmony with the present result Hajong (2017) reported that transplanting of a week old seedling raised in polybag recorded significantly higher grain yield than the rest of the treatment combination. In conformity to the present trial Kumar *et al.* (2014) who reported that grain yield of transplanted maize was significantly influenced by the interaction between methods of nursery to raise seedlings and age of seedlings at the time of transplanting. Dhillon *et al.* (1990) also reported that maximum amount of grain yield from treatments that receive transplanting of polybag and four true leaf seedlings might be due to the presence of higher number of cobs per plant, cob length and number of grains row^{-1}. The correlation analyses also confirmed that grain yield was positively and significantly correlated with the number of cobs per plant, number of grains row^{-1} and cob length.

Table 4.Interaction effect of types of seedlings and their growth stages on the number of cobs per plant and grain yield of maize

	NCpP		GY(t ha^{-1})	
	Types of Seedling		Types of Seedling	
Seedling growth stage	Bare Rooted	Poly Bagged	Bare Rooted	Poly Bagged
1	1.20de	1.33cd	5.5d	8.5b
2	1.07e	1.53b	5.7d	8.9b
3	1.13e	1.20de	6.6dc	7.6bc
4	1.20de	1.73a	8.7b	10.7a
5	1.13e	1.47bc	6.5dc	8.6b
Control	1.46bc		8.6b	
LSD (p<0.05)	**0.1749**		**1.4487**	
CV (%)	**3.62**		**9.07**	

NCpP=number of cobs per plant; GY= grain yield; CV= coefficient of variation; LSD=least significance difference

Stover yield

The stover yield was highly significantly (P<0.01) affected both by main effects of seedling types, growth stages of seedlings and their interaction. The highest stover yield (20.31t ha^{-1}) was observed at transplanting of polybagged seedlings and at the control (20.26t ha^{-1}) produced statistically equal amount of stover yield with transplanting of polybagged seedlings, whereas bare-rooted seedlings provide the lowest amount of stover yield (16.22t ha^{-1}) (Table 3). In conformity with this result, Biswas *et al.* (2009) concluded that direct planted maize gave the highest stover yield (9.66t ha^{-1}) and it was also similar to tray (cup) nursery (9.13t ha^{-1}) whereas the lowest stover yield was found in the dry bed nursery (8.48t ha^{-1}).

Regarding growth stages of seedlings, the highest (21.6, 21.05 and 20.26t ha^{-1}) value of stover yield was recorded from treatment which received transplantation of four true leaf, five true leaf seedling and from the control, respectively while, the lowest stover yield (15t ha^{-1}) was noticed from the transplantation of one true leaf seedlings and which was also at parity with the rest of seedlings growth stage (Table 3). In partial agreement with the present work Aihole (2012) reported that, non-liner increment in dry stover yield was recorded at planting of different growth stage seedlings. Biswas (2008) also reported that, direct seeded maize produced the highest stover yield and that was at par with 14-day old seedlings. In contrary with this work Mrityunjoy (2015) reported that stover yield was decreased progressively with the increase of seedling age from direct planting to transplanting of 14 and 21-day old seedlings.

Not only the main effects of seedling types and their growth stages, but also the interaction effect of the two factors affect stover yield of maize highly significantly (P<0.01). The highest value of stover yield (27.77t ha^{-1}) was recorded from the treatments which received transplantation of four true leaf seedlings which were grown by polybag. The stover yield of the above mentioned treatments is higher than the stover yield obtained from the control which gave 20.26t ha^{-1}. But the lowest (14.23t ha^{-1}) stover yield was recorded from the treatment combination and transplantation of polybagged seedlings having one true leaf growth stage (Table 5). Recording of the highest weight of stover yield from transplanting of polybag seedlings and four and five true leaf seedlings might be due to the observation of higher value of number of cobs per plant, cob length and biomass yield from transplanting of the same treatments. The correlation analysis confirmed also, stover yield had positive and very highly significant correlation with number of cobs per plant, cob length and biomass yield ha^{-1}.

Table 5. Interaction effect of types of seedlings and their growth stages on Stover yield and harvest index of maize

	SY (t ha^{-1})		HI (%)	
	Types of Seedling		Types of Seedling	
Seedling growth stage	Bare Rooted	Poly Bagged	Bare Rooted	Poly Bagged
1	15.77bc	14.23c	26.10de	37.40ab
2	16.87bc	16.77bc	25.40de	35.07cab
3	14.81bc	18.93b	31.30cdb	29.23cde
4	15.43bc	27.77a	40.97a	23.87e
5	18.23bc	23.87ab	26.30de	26.50de
Control	20.26b		29.60cdb	
LSD (p<0.05)	4.4485		6.748	
CV (%)	3.62		9.07	

SY= Stover yield; HI=harvest index; CV= coefficient of variation; LSD=least significance difference

Harvest index

The harvest index was not significantly (p>0.05) affected by both the main effect of seedling types and their growth stages. However, the interaction of types of seedlings and their growth stages was very highly significantly (P<0.001) affect harvest index of transplanted maize. In this study, the highest (40.97) percent of harvest index was observed from transplanting of four true leaf seedlings which were grow as bare-rooted. The lowest (23.87) percent of harvest index was present from four true leaf seedlings grown with polybag, whereas the control had 29.60% of harvest index (Table 5). In disagreement to the present result Hajong (2017) reported that the interaction effect between seedling raising methods and seedling age were found non-significant on harvest index of transplanted sorghum.

Correlation analysis of yield and yield related parameters of maize

Number of cob per plant was correlated strongly, positively and significantly with cob length, number of grains row^{-1}, biomass yield, number of grains cob^{-1}, stover and grain yield (Table 6). This shows that an increased in number of cob per plant leads to increase in biomass, grain and stover yield of maize. Positive and significant association was observed between grain yield and cob per plant, cob length, number of grains row and biomass yield. The current result is in line with the report of Inamullah *et al*. (2011) who states that grain yield showed positive and highly significant correlation with cob length. Similarly, Nwokwu (2016) also stated that grain yield has significant and positive association with all the parameters except with leaf area index and days to 50% tasselling.

Table 6. Simple correlation analysis among maize agronomic parameters

	NCpP	CL	NGpR	NGpC	GY	BY	SY	HI
NCpP	1							
CL	0.78***	1						
NGpR	0.80***	0.71***	1					
NGpC	0.56**	0.54**	0.84***	1				
GY	0.42*	0.56**	0.41*	0.27ns	1			
BY	0.70***	0.80***	0.79***	0.67***	0.46*	1		
SY	0.63**	0.68***	0.73***	0.64**	0.14ns	0.94***	1	
HI	-0.14ns	-0.06ns	-0.23ns	-0.25ns	0.65***	-0.37*	-0.65**	1

Note: NCpP = number of cobs per plant; CL= cob length; NGpR= number of grains row^{-1}; NGpC= number of grains cob^{-1}; GY= grain yield; BY= biomass yield; SY= Stover yield; HI= harvest index; ns= not significant; * = significant; **= highly significant; ***= very highly significant

Partial budget analysis

Table 7.Partial budget analysis

Treatments	AYBA (t ha^{-1})		AYAA (t ha^{-1})		Unit price (Birr t ha^{-1})		Total sale price (Birr ha^{-1})		GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})
	GY	SY	GY	SY	GY	SY	GY	SY			
BR1TL(T1)	6.11	15.77	5.5	14.19	8,000	200	44,000	2,838	46,838	4,400.00	42,438
BR2TL(T2)	6.33	16.87	5.7	15.18	8,000	200	45,600	3,036	48,636	4,500.00	44,136
BR3TL (T3)	7.33	14.81	6.6	13.33	8,000	200	52,800	2,666	55,466	4,600.00	50,866
BR4TL(T4)	9.66	15.43	8.7	13.89	8,000	200	69,600	2,778	72,378	4,700.00	67,678
BR5TL(T5)	7.22	18.23	6.5	16.41	8,000	200	52,000	3,282	55,282	4,800.00	50,482
PB1TL(T6)	9.44	14.23	8.5	12.81	8,000	200	68,000	2,562	70,562	5,650.00	64,912
PB2TL(T7)	9.88	16.77	8.9	15.09	8,000	200	71,200	3,018	74,218	5,750.00	68,468
PB3TL(T8)	8.44	18.93	7.6	17.04	8,000	200	60,800	3,408	64,208	5,850.00	58,356
PB4TL(T9)	11.88	27.77	10.7	24.99	8,000	200	85,600	4,998	90,598	5,950.00	84,648
PB5TL(T10)	9.55	23.87	8.6	21.48	8,000	200	68,800	4,296	73,096	6,050.00	67,046
DS (T11)	9.55	20.26	8.6	18.23	8,000	200	68,800	3,646	72,446	1400	71,046

Note: AYBA= average yield before adjusting; AYAA= average yield after adjusting; GY= grain yield; SY= Stover yield; GB= gross benefit; TVC= total variable cost; NB= net benefit; BR1TL= bare rooted one true leaf; BR2TL= bare rooted two true leaf; BR3TL= bare rooted three true leaf; BR4TL= bare rooted four true leaf; BR5TL= bare rooted five true leaf; PB1TL=poly bagged one true leaf ; PB2TL= poly bagged two true leaf; PB3TL= poly bagged three true leaf;PB4TL= poly bagged four true leaf; PB5TL= poly bagged five true leaf; DS= direct seeded (control)

Note: cost of labor, compost, sand, polyetheylen bag per roll, maize grain and maize stove per 100 kg was 50-80, 100, 100, 500, 800 and 20 Birr based on the local market respectively.

The result of the partial budget analysis also confirmed that transplanting of polybag seedlings at four true leaf stage resulted the highest value of net benefit (84,648 Birr ha-1) with acceptable range of marginal rate of return. In the current condition, all the treatments are dominated except the control treatment and treatment nine (transplanting of polybag seedlings at four true leaf stage) (Table 8). This indicates that, transplanting of polybag seedlings at four true leaf stage is economically feasible and can be recommended tentatively for maize production in the study area and similar agro-ecologies.

Table 8. Dominance and marginal rate of return (MRR) analysis

Treatment	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	Dominance	MRR (%)
DS (T11)	1400	71,046		-
BR1TL(T1)	4,400	42,438	D	
BR2TL(T2)	4,500	44,136	D	
BR3TL (T3)	4,600	50,866	D	
BR4TL(T4)	4,700	67,678	D	
BR5TL(T5)	4,800	50,482	D	
PB1TL(T6)	5,650	64,912	D	
PB2TL(T7)	5,750	68,468	D	
PB3TL(T8)	5,850	58,356	D	
PB4TL(T9)	5,950	**84,648**		298
PB5TL(T10)	6,050	67,046	D	

Note: TVC= total variable cost; NB= net benefit; D= dominated; MRR (%)= marginal rate of return in percent; BR1TL= bare-rooted one true leaf; BR2TL= bare-rooted two true leaf; BR3TL= bare-rooted three true leaf; BR4TL= bare-rooted four true leaf; BR5TL= bare-rooted five true leaf; PB1TL=polybagged one true leaf ; PB2TL= polybagged two true leaf; PB3TL= polybagged three true leaf;PB4TL= polybagged four true leaf; PB5TL= polybagged five true leaf; DS= direct-seeded (control)

Conclusion

The agronomic results of the present study showed that transplanting of polybag seedlings at four true leaf stages gave the highest (10.7t ha^{-1}) grain yield of maize as compared to other treatments. The result of the partial budget analysis also confirmed that transplanting of polybag seedlings at four true leaf stage resulted the highest value of net benefit (84,648 Birr ha^{-1}). Transplanting of polybag seedlings at four true leaf stages is economically feasible and can be recommended tentatively for maize production in the study area and similar agro-ecologies. To come up with workable recommendations, however, there is a need for further similar studies in similar agro-ecology and soil types across location and season. It is also advised to repeat the study in areas having terminal moisture stress for maize production.

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