Effect of Method of Sowing and Time of Di-Ammonium Phosphate (DAP) Fertilizer Application, on Yield and Yield Components of Tef (\textit{Eragrostis tef} Trotter) At Shebedino, Southern Ethiopia

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Abstract

Time of DAP application and sowing method vary from farmer to farmer. Therefore, there is a need to determine time of DAP and sowing method recommendations for tef (\textit{Eragrostis tef} (Zucc) Trotter). Accordingly, an experiment was conducted to evaluate the effect of sowing method and time of DAP application on yield and yield components of tef at Shebedino, Southern Ethiopia in 2012 cropping season. DZ-37 tef variety was used as a test crop. A factorial combination of planting method (row planting and broadcasting) and five times of DAP fertilizer application (at planting, two, four, six and eight days before planting) was laid out in Randomized Complete Block design (RCBD) with four replications. Row sowing and DAP applied two days before planting had significantly affected days to heading and maturity, plant height, first growth rate, number of tiller and panicle, thousand seed weight, grain, straw and total biomass yields and harvest index. Days to emergence and panicle length were significantly affected by broadcasting and application of fertilizer two days before planting. Row sowing hastened heading and maturity by 1 day and increased growth rate by 23.46% than broadcasting; and DAP applied two days before planting hasten the emergence, and panicle length by 4 and 5 days, respectively, than DAP applied eight days before planting. Row sowing had 10, 24.8 and 23.8% more panicles, grain and biomass yields respectively, than broadcasting. DAP applied two days before sowing increased panicles, grain and biomass yields by 41.7, 62.1 and 59.9% respectively, than DAP applied eight days before sowing. Interaction of row sowing and DAP applied at the time of sowing, had 54.7 and 1.07% more 1000 seed weight and harvest index respectively, than broad casting and DAP applied at the time of sowing. Row sowing was found to be economically acceptable with Marginal Rate of Return (MRR) of 627.7% with 6775.6 Birr ha⁻¹ more income from grain yield than broadcasting. Row sowing and DAP applied two days before planting had 80.85 Birr ha⁻¹ more additional income from straw than broadcasting. Therefore, row sowing and DAP application two days before planting could be recommended as an economically feasible choice for the study area.

Keywords: Sowing method; Row seeding; Broadcasting; Time of fertilizer/DAP application before planting

Introduction

Tef (\textit{Eragrostis tef} (Zucc) Trotter) is a small-seeded cereal indigenous to Ethiopia and originated in Ethiopia between 4000 and 1000 BC. Tef is among the major cereal crops in Ethiopia and occupies about 22.6% of the total cereals' land [1].

In Ethiopia, tef performs well in medium altitude (1700-2400 masl). The length of growing period considering rainfall of 450 to 550 mm and evapo-transpiration of 2-6 mm day⁻¹ ranges from 60 to 180 days. Depending on variety and altitude, tef requires 90 to 130 days for growth [2].

Tef ranks the lowest yield compared with other cereals grown in Ethiopia. The cause for lower productivity is lodging, method of planting and fertilizer application. Meanwhile the combined effect of those factors result up to 22% reduction in grain and straw yield [2].

The most common way of planting tef is by broadcasting the small seed at the rate of 25-30 kg ha⁻¹ [3]. This sowing method results up to 22% reduction in grain and straw yield [2]. To minimize the problem of lodging on tef, low seed rate, row planting late sowing, application of plant growth regulators, appropriate rate and timing of fertilizer application [5,6].

There is much advantage from early application [7]. But the right time of fertilizer application before planting is not known; due to limited research work on early application. Therefore, there are controversies among Ethiopian farmers regarding appropriate time of DAP fertilizer application before planting. Some farmers prefer to apply DAP four days before planting, while others prefer to apply three days before planting, the remaining prefer to apply two and one day before planting; which might result on loss of fertilizer and reduction in yield [8]. Hence, this study was initiated with the following objectives:

To evaluate the effect of sowing method and time of Di-Ammonium Phosphate (DAP) fertilizer application on growth and yield of tef

To see the interactive effect of sowing method and time of DAP fertilizer application on growth and yield of tef

To identify the optimum sowing method & time DAP fertilizer application in tef production

Materials and Methods

Site description

This study was conducted at Taremessa Kebele of South Ethiopia.

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The kebele is situated at 7° 4’ N and 44° E with an elevation of 1980 masl; which are ideal for the production of tef. The mean annual rain fall varies from 900-1500 mm. The dominant crops growing around the experimental area are enset (Ensete ventricosum), maize (Zea mays L.), tef, different vegetables and Chat (Khat edulis) [9].

Experimental treatments and design

The experiment consisted of two factors, method of sowing and time of fertilizer application; arranged in randomized complete block design (RCBD). Times of fertilizer (DAP) application (0, 2, 4, 6 and 8 days before planting) and methods of sowing (broad casting and row sowing), were arranged as factorial with four replications.

Experimental procedure

DZ-Cr-37 (Tsedeay) variety was used as a test crop; which is most widely grown variety in the relatively low altitude and moisture prone areas [10].

The experimental field was prepared by using oxen plow and plowed four times, before planting. The experimental plot size was 2 m × 2.5 m (5 m²) and the space between plots was 0.5 m; which had 0.2 m intra row space.

DAP fertilizer was used at the rate of 100 kg ha⁻¹ as source of N and P; and Urea was applied at the rate of 50 kg ha⁻¹; in which 1/3 at planting and 5 kg ha⁻¹ for broad casting and row sowing respectively.

Soil sampling and analysis

Sixteen random soil samples (0-20 cm depth) from the experimental field were thoroughly mixed to make a composite. The sample was air dried and ground to pass 2 mm sieve and necessary parameters such as soil texture, available P, pH and CEC were determined. For the determination of OC and N 1 mm sieve was used. Soil texture was measured potentiometrically in the 1:2.5 soil: water mixture by using a procedure described by Olsen method [12]. The pH of the soil was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Walkely and Black wet oxidation method [13]. Cation Exchange Capacity (CEC) was determined by Ammonium Acetate method [14].

Data collection

Phenological data

Days to 50% emergence: number of days from sowing up to the date when 50% of the plants emerged in a plot.

Days to 50% heading: number of days from sowing up to the date when the tips of the panicles first emerged from the main shoot, on 50% of the plant in a plot.

Days to 90% maturity: number of days from the date of sowing up to the date when 90% of the crop stands in a plot changed to light yellow color.

Growth data

Plant height (cm): It was taken at an interval of 20 days; by taking six randomly selected plants and measured from the base of the main stem to the tip of the panicle.

Growth Rate: It was the ratio of the differences between two consecutive dry matter production measured at difference time [GR=Δ DW/ΔT] [14].

Growth rates (GR₁, GR₂ and GR₃) were calculated according to (Echarte et al.), as following [14]:-

\[
GR_1 = \frac{H_2 - H_1}{T_2 - T_1} \quad GR_2 = \frac{H_3 - H_2}{T_3 - T_2} \quad GR_3 = \frac{H_4 - H_3}{T_4 - T_3}
\]

Where,

\[
GR_1 = \text{First growth rate} \quad T_1 = 20 \text{ days after emergence}
\]

\[
GR_2 = \text{Second growth rate} \quad T_2 = 40 \text{ days after emergence}
\]

\[
GR_3 = \text{Third growth rate} \quad T_3 = 60 \text{ days after emergence}
\]

\[
H_1 = \text{Height of plant at time } t_1
\]

\[
H_2 = \text{Height of plant at time } t_2
\]

\[
H_3 = \text{Height of plant at time } t_3
\]

\[
H_4 = \text{Height of plant at time } t_4
\]

Tillers number (m²⁻¹): - to determine the capacity of tillering per hectare, 10 cm × 20 cm area was demarcated and the number of plants existed in that area was counted at the time of emergence. Then the second counting was done at flowering on demarked area; because maximum tillers produced during vegetative phase and senescence occurs at maturity [15]. Finally the difference between the first and second count was taken as number of tiller in 10 cm × 20 cm area and converted into number of tiller per plant, by dividing it to number of plant in the first count.

Panicles per plant: six plants were randomly taken and the average number of panicles per plant was considered.

Panicle length (cm): length of the panicle was measured by selecting six plants randomly and measuring from the node (the first panicle branch started) to the tip of the panicle.

Yield and yield components

Total above ground biomass (kg):- Due to lack of oven dryer machine, total above ground biomass was measured after complete sun-drying for two days

Straw yield (kg): was measured by subtracting grain yield per plot from the total above ground biomass.

Grain yield (kg ha⁻¹): yield from every plot

Thousand seed weight (g): the seeds were taken from each plot and 1000 seeds counted by hand and then weighed.

Harvest index: - the ratio of grain yield to the above ground (shoot) biomass. [HI= Grain yield/above ground biomass].

Economic analysis

For economic analysis, a simple partial budget analysis was employed using CIMMYT approach [16]. For partial budget analysis, the factors with significant effect were considered. The yield was adjusted by subtracting 10% from average gain yield. Than after, gross yield benefit was obtained by multiplying the adjusted yield by the price of grain (13 birr kg⁻¹). Net benefit was calculated, by subtracting labor cost from gross yield. Finally marginal rate of return (MRR) was obtained, by obtaining marginal net benefit to the marginal cost and expressed as percentage (CIMMT). The mean market price of tef was obtained by assessing the market at harvest (2012 cropping season).
Data analysis

The various agronomic data were analyzed using the general linear model (GLM) procedures of the SAS statistical software (SAS Institute) to evaluate the effect of sowing method and time of fertilizer application and their interaction. Least Significant Difference (LSD) test at P ≤ 0.05 was used to separate means whenever there were significant differences.

Results and Discussion

Physicochemical properties of the experimental soil

The results indicated that the experimental soil was clay loam textured; having organic carbon content (OC) of 2.54% (Table 1). The soil had high OC in accordance with Sahlemedhin, who rated OC between 1.74-2.90% as high. The CEC of the soil was 23.87 cmol kg⁻¹, which could be considered as medium [13]. According to Olsen et al. P rating (mg kg⁻¹), P content of <3 is very low, 4 to 7 is low, 8 to 11 is medium, and >11 is high. Thus, the experimental site of available P content is high. The pH of the soil was 4.98, which is within the range of 4 to 8 suitable for tef production [17]. Total N of the soil (0.16 %), is medium; as rated by Havlin et al. who rated total N between 0.15 to 0.25% as medium [18].

Crop Phenology

Days to emergence: Days to 50% crop emergence was significantly affected both by method of sowing and time of fertilizer application (P ≤ 0.001). However, their interaction did not have any significant effect on crop emergence.

Broadcasting shortened days to emergency by 3-days than row sowing (Table 2). The result agrees with the finding of Klosterboer and Turner, who indicated rice in the broadcast, emerges earlier than row sowing [19]. The row sown tef was placed relatively deeper than that of broadcasting. The finding was in contrast to the report of Evert et al., who found earlier emergence of tef on the surface compared to deeper planted tef [20]. Because of poor seed to soil contact.

Fertilizer applied eight days before sowing delayed emergency by 2-days than that applied two days before sowing (Table 2). This might be attributed to the high loss of DAP fertilizers from the earlier application before it is used by the plant. Especially N, which is highly soluble and may be lost from the soil-plant system by leaching, denitrification, volatilization and erosion [21].

Days to heading: Both method of sowing and time of fertilizer application had a significant (P ≤ 0.001); but interaction did not have a significant effect on days to heading. Row sowed tef was head 1-day earlier than broadcasted (Table 2), which may be due to little weed competition and efficient use of fertilizer than broadcasted one [22].

Days to heading was enhanced by 4 days on DAP applied two days before sowing, compared to that of DAP applied eight days before sowing (Table 2). Thus days to heading for application of DAP two days before sowing is smaller; due to minimum loss fertilizer contributes for growth of crop [23].

Days to maturity: Days to 90% maturity were significantly (P ≤ 0.001) affected by both sowing method and time of fertilizer application; but their interaction not significant.

Row sowed tef matured 1-day earlier than broadcasted (Table 2). The result is in line with Delesa, who reported rice planted by broadcasting matured later than rows [24]. The possible reason is that, less weed infestation and better use of fertilizer in row planting as compared to broadcast; specially P enhanced maturity [23,25]. Application of fertilizer at planting resulted in 1-day delay and 4-days earlier mature compared to those applied two and eight days before sowing, respectively (Table 2). Thus, applying fertilizer two days before sowing enhanced maturity and this was because of time of application is one of the factor influencing crops phyiology and growth [26].

Growth parameters

Plant height: Both sowing method and time of fertilizer application had very high significant (P ≤ 0.001) effect on plant heights. However the interaction effect did not have significantly affect plant height.

| Treatments       | 50% Emergence | 50% Heading | 90 % Maturity |
|------------------|---------------|-------------|---------------|
|                   | Method of sowing |            |               |               |
| Broad casting     | 7b            | 46a         | 68a           |
| Row sowing       | 10a           | 45b         | 67b           |
| LSD (5%)         | 0.24          | 0.55        | 0.80          |
| CV (%)           | 4.32          | 1.87        | 1.84          |
| Time of fertilizer application |
| At planting      | 8c            | 45cd        | 66cd          |
| 2-DBP            | 8c            | 44d         | 65d           |
| 4-DBP            | 9b            | 46bc        | 67bc          |
| 6-DBP            | 9b            | 47b         | 68ab          |
| 8-DBP            | 10a           | 48a         | 70a           |
| LSD (5%)         | 0.54          | 1.25        | 1.80          |
| CV (%)           | 4.32          | 1.87        | 1.84          |

DBP: Days before Planting, the same letter in a column of each factor shows a non-significant difference at 5 probability level.

Table 1: Physico-chemical properties of the experimental soil.

| Depth (cm) | pH (H₂O) | CEC (cmol kg⁻¹) | OC (%) | Total N (%) | Av.P (mg kg⁻¹) | Particle size distribution (%) | Textural |
|------------|----------|-----------------|--------|-------------|----------------|-------------------------------|---------|
| 0-20       | 4.98     | 23.87           | 2.54   | 0.16        | 27.4           | sand: clay: silt = 32:30:38    | Clay loam |

Table 2: Effect of method of sowing and time of DAP application on the days to emergence, heading and maturity of tef.
Row sowing had better heights, at all of four measurements (PH, PH₁, PH₂, and PH₃) than broadcasting and also contributed for 15, 24, 12 and 3% increments in plant heights, respectively (Table 3). These are due to smaller space among plants in broadcast resulting in higher competition for nutrients; while in row sowing there was wider space and thus relatively less plant competition for nutrients [27]. Also, Caliskan et al., reported taller and more branched plants at the lower plant densities of sesame.

Application of fertilizer two days before sowing had 25% more plant height than DAP applied at sowing on the first measurement. Whereas application of fertilizer two days before sowing had 42, 25.6 and 8.7% higher plant height than that of applied eight days before sowing on PH₂, PH₁ and PH₃, respectively. These were because of maximum use of N and P with minimum loss resulting in maximum growth in height on fertilizer applied two days before sowing [21,28].

**Growth rate:** Sowing method, time of fertilizer application and their interaction were not significant effect on all growth rates; except method of sowing had significant (P ≤ 0.05) effect on the first growth rate. Row sowing had 23% more fast growth than broadcasting on first growth rate (Table 3). The non-significant effect on others growth rate were due to efficient utilization of applied DAP fertilizer at earlier growth stage. Especially N is a constituent of chlorophyll, proteins and nucleic acids, which are essential for plant growth [29].

**Panicle length:** Sowing method and time of fertilizer application significantly (P ≤ 0.001) affected panicle length, but their interaction was not. Broadcasting increased panicle length by 11% more than row sowing (Table 3). Because less tillering on broadcasting due to many weed density [25]. This contributes to growth of panicle length due to minimum competition for nutrients among tillers. Mean time the number of tiller negatively correlated with panicle length on [30].

Fertilizer applied two days before sowing had 16% more and 13% less panicle length than fertilizer applied eight days earlier sowing and at time of sowing, respectively. This might be due to maximum utilization of nutrients on fertilizer applied two days before sowing and at the time of sowing. Because time and rate of fertilizer application has significant effect on both growth and yield [31].

**Panicle number:** Sowing method and time of fertilizer application significantly (p ≤ 0.001) affected number of panicles per plant; but their interaction was not significant. Row sown had 10% more panicle numbers than broadcasted (Table 3), because of better root growth in the case of row planting. This favors the growth and contributes to panicles per a plant [26,32].

Application of DAP eight days before sowing and at time of sowing had 42 and 8% less panicle number, respectively, than applied two days before sowing (Table 3). These because of the time of fertilizer application, particularly those containing N and P affects panicle number [33].

**Tillers:** Sowing method, time of fertilizer application and their additive effect significantly (P<0.001) affected the number of tillers.

The additive effect of row sowing and DAP applied two days before sowing had 5% more tillers than the additive effect of row sowing and DAP applied at the time of sowing. Whereas the additive effect of broadcasting and DAP applied eight days before sowing had delayed the growth by 83% compared with additive effect of row sowing and fertilizer applied at sowing (Table 4). These might be due to maximum loss of N, when DAP was applied eight days earlier to sowing, which could result to less tillering; because N stimulates tillering due to its effect on cytokinin synthesis [31].

**Yield and yield components**

**Total biomass:** Sowing method and time of fertilizer application significantly (p ≤ 0.001) affected biomass yield; although their interaction were not significant. Row sowed tef yielded 23.8% more biomass than broadcasted (Table 5). Because of better growth in row sowing, due to easy absorption of photosynthetically active radiations [34].

Application of DAP at the time of sowing resulted in 52.5 % more biomass than the treatment with DAP applied eight days prior to sowing. Whereas applying of DAP at the time of sowing 15 % less biomass than DAP applied two days before sowing (Table 5), this might be due to maximum use of applied fertilizer on fertilizer applied two days prior sowing. Because of efficient utilization of applied fertilizer increased vegetative growth, which resulted for higher biomass production [35].

**Straw yield:** Time of fertilizer application significantly (p ≤ 0.5) affected biomass yield; although sowing method and interaction of time of fertilizer application and sowing method were not significant.

| Treatments                  | PH₁     | PH₂     | GR₁     | PH₃     | GR₂     | PH₄     | GR₃     | PL       | PN       |
|-----------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Method of sowing            |         |         |         |         |         |         |         |         |         |
| Broad casting               | 11.54b  | 29.80b  | 0.98b   | 67.84b  | 1.89    | 94.00b  | 1.32    | 20.79a  | 9b      |
| Row sowing                  | 13.56a  | 39.17a  | 1.28a   | 77.30a  | 1.90    | 97.32a  | 1.50    | 18.51b  | 10a     |
| LSD (5%)                    | 1.14    | 3.39    | 0.23    | 3.66    | 0.21    | 1.58    | 1.04    | 2.31    | 0.34    |
| CV (%)                      | 14.00   | 15.13   | 31.30   | 7.78    | 17.54   | 2.54    | 11.3    | 5.86    | 5.54    |
| Time of fertilizer application |        |         |         |         |         |         |         |         |         |
| At planting                 | 11.48b  | 38.16ab | 1.32    | 77.95ab | 2.00    | 97.77ab | 2.69    | 23.75a  | 11b     |
| 2-DBP                       | 15.40a  | 43.00a  | 1.38    | 84.00a  | 2.05    | 100.15a | 1.34    | 20.61b  | 12a     |
| 4-DBP                       | 14.60a  | 35.80ab | 1.05    | 71.50bc | 1.78    | 95.45bc | 1.20    | 18.94bc | 10c     |
| 6-DBP                       | 11.37b  | 30.58bc | 0.96    | 66.90cd | 1.82    | 93.75cd | 0.82    | 17.63c  | 8d      |
| 8-DBP                       | 9.89b   | 24.97c  | 0.90    | 62.50d  | 1.87    | 91.40d  | 1.01    | 17.33c  | 7e      |
| LSD (5%)                    | 2.58    | 7.63    | 0.51    | 8.24    | 0.48    | 3.56    | 2.33    | 1.68    | 0.77    |
| CV (%)                      | 14.00   | 15.13   | 31.30   | 7.78    | 17.54   | 2.54    | 11.3    | 5.86    | 5.54    |

DBP: Days Before Planting; PH: Plant Height (PH₁ was measured 20 days after emergence; PH₂-measured 40 days after emergence; PH₃-measured 60 days after emergence and PH₄ was measured 80 days after emergence); GR: Growth Rate (GR₁-calculated from PH₁ & PH₂; GR₂-calculated from PH₂ & PH₃; GR₃-calculated from PH₃ & PH₄); PL: Panicle Length and PN: Panicle Number. The same letter in a column of each factor shows a non-significant difference at 5% probability level.

Table 3: Effect of time of DAP application and sowing method on growth of tef.
Application of DAP at the time of sowing and two days prior to sowing resulted in 18 and 23.3% more straw yield, respectively than the treatment with DAP applied eight days prior to sowing (Table 5). This might be due to maximum use of applied fertilizer, with little loss on applied at the time of sowing and two days prior to sowing. Because of efficient utilization of applied fertilizer increased vegetative growth, which contribute to higher straw yield [34].

**Grain yield:** Sowing method and time of fertilizer application (P<0.001) had significant effect on grain yield; but no interaction effect. Row sown increased grain yield by 24.8% over broadcasted (Table 5). This might be uneven seed distribution on broadcasting, which results in excess nutritional competition at certain areas and no competition on other areas of the field and thus less grain yield productivity [24].

Application of DAP two days before sowing increased grain yield by 15.6% over DAP applied at the time of sowing, whereas DAP applied eight days before sowing decreased grain by 55.1% compared to application at sowing (Table 5). These could attributed by minimum loss through leaching and volatilization on DAP applied two days before sowing and which resulted in better growth (Figure 1) [35].

**Thousand Seed weight:** Sowing method, time of fertilizer application and their additive effect had significant (p ≤ 0.001) effect on thousand seed weight. Additive effect of row sowing and fertilizer application two days before sowing had 26.7% more thousand seed weight than additive effect of row sowing and DAP applied at sowing. Whereas as the additive effect of broadcasted and DAP applied eight days prior sowing was weighted 82.4% less compared in weight to row sowed and DAP applied at sowing (Table 6). These might be because of combined effect of row sowing, which enhances efficiently utilization of applied fertilizer [36] and appropriate rate of N fertilizer at correct time, which optimizes grain yield and quality [37].

**Harvest index:** Main effects and additive effect had significant effect on harvest index. Combined effect of row sowing and fertilizer application two days before sowing had 17.2% more harvest index than additive effect of broadcasting and application of DAP eight days prior to sowing (Table 4). These might be due to; row sowing had less weed competition and efficient use of applied fertilizer [38]. This results for increment vegetative growth by applied N, which in turn increase grain yield by improving cumulative solar radiation intercepted by the crop [12].

### Table 4: Additive effects of time of fertilizer application and sowing method on tef tillering.

| Treatments   | TBM  | SY  | GY  |
|--------------|------|-----|-----|
|              | Kg ha⁻¹ |    |     |
| Sowing Method|      |    |     |
| Broad casting| 1092.5b | 97.05 | 995.45 |
| Row sowing   | 1432.5a | 108.5 | 1324.0 |
| LSD (5%)     | 97.0  | 11.6 | 149.9 |
| CV (%)       | 19.5  | 17.4 | 19.9 |
| Time of fertilizer |      |    |     |
| At planting  | 1525.0ab | 110.0a | 1415.0a |
| 2-DBP        | 1793.8a | 117.5a | 1676.3ab |
| 4-DBP        | 1331.3b | 101.3ab | 1230.0b |
| 6-DBP        | 937.5c | 95.0ab | 842.5c |
| 8-DBP        | 725.0c | 90.1b | 634.9c |
| LSD (5%)     | 359.9  | 26.1 | 337.5 |
| CV (%)       | 19.5  | 17.4 | 19.9 |

**DBP:** Days before Planting; **LSD:** Least Significant Difference and **CV:** Coefficient of Variations.

### Table 5: Effects of time of DAP application and sowing method on yield and yield components of tef.

| Treatments | TBM  | SY  | GY  |
|------------|------|-----|-----|
|            | Kg ha⁻¹ |    |     |
| Sowing Method |      |    |     |
| Broad casting | 1092.5b | 97.05 | 995.45 |
| Row sowing | 1432.5a | 108.5 | 1324.0 |
| LSD (5%)  | 97.0  | 11.6 | 149.9 |
| CV (%)    | 19.5  | 17.4 | 19.9 |
| Time of fertilizer |      |    |     |
| At planting | 1525.0ab | 110.0a | 1415.0a |
| 2-DBP | 1793.8a | 117.5a | 1676.3ab |
| 4-DBP | 1331.3b | 101.3ab | 1230.0b |
| 6-DBP | 937.5c | 95.0ab | 842.5c |
| 8-DBP | 725.0c | 90.1b | 634.9c |
| LSD (5%) | 359.9  | 26.1 | 337.5 |
| CV (%)  | 19.5  | 17.4 | 19.9 |

**DBP:** Days before Planting; **CV:** Coefficient of Variations; **TBM:** Total Bio Mass; **SY:** Straw Yield and **GY:** Grain Yield.

**Figure 1:** Effect of time of DAP application on Grain yield of tef.
Association of grain yield with yield and yield components

Stepwise multiple linear correlation analyses were carried out using treatment means to determine the effects of method of sowing and time of fertilizer on the grain yield formation. Grain yield considered as dependant, whereas plant height, growth rate, tillers, panicles, panicle length, thousand seed weight, straw yield, total biomass and harvest index were taken as explanatory variables (Table 7).

Grain yield was positively and significant (P<0.001) associated with plant heights taken at four different times, first growth rate, number of tillers and panicles, panicle length and thousand seed weight, r=0.60, 0.69, 0.72, 0.70, 0.51, 0.8, 0.6 and 0.81, respectively. Similar correlations were reported in barley by Mekonnen and Alam et al. On the other hand, grain yield was associated negatively with thir third growth rate (r=-0.69***); which was in line with the report of Getachew on bread wheat.

Partial budget analysis

The return obtained from row planting was above the minimum acceptable marginal rate of return (100%) [16], which is 627.7% and contributes to 6775.6 Birr ha⁻¹ more income as compared to broadcasting. The combination of row sowing and fertilizer applied two days prior to sowing had increased straw yield 60% more than broadcasting and application of DAP eight days before sowing (Table 8), which contributed more 80.85 birr ha⁻¹ than broadcasted and eight days earlier applied. Thus, in order to obtain benefit from straw and grain, row sowing and fertilizer application two days before sowing could be recommended for farmers in this area.

Conclusion

The economic analysis indicated that row sowing had acceptable MRR (627.7%); and 6775.6 Birr ha⁻¹ more grain yield income than...
broadcasting tef. Combination of row sowing and DAP applied two days prior to sowing had additional income from straw (80.85 birr ha⁻¹) compared to broadcasting and application of DAP eight days before sowing. Thus, it is possible to recommend that, row sowing and DAP application two days before planting for tef production in the trial area. However, it is advisable to undertake further research across soil type, years and locations to draw sound recommendation on a wider scale.

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