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Evaluation of hot pepper (*Capsicum annuum* L.) cultivars for growth and dry pod yields against different blended fertilizer and nitrogen rates in raya Azebo, Southern Tigray

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Abstract
Hot pepper (*Capsicum annum* L.) is the most widely cultivated and economically important crop. However, its production and productivities are constrained by different factors in which Cultivar and fertilizer level are the major ones. Thus, the experiment was conducted on two hot pepper cultivars (Melka Shote and Melka Awaze) and six rates NPSZn + urea; to determine the growth and yield response of hot pepper cultivars to different levels NPSZn + urea and interaction effect of both factors. A factorial RCBD (2*6) was used for the experiment and each treatment was replicated thrice. Growth, penological and yield data were collected and and analyzed using SAS version 9.3. ANOVA revealed that plant height, days to first harvest, total leaf area, leaf area index, number of pods plant^{-1}, marketable, unmarketable and total dry pod yield and pod length were significantly (p<0.05) affected by the interaction effect of cultivars and NPSZn + urea rates. The main effect of cultivars and NPSZn + urea exerted highly significant (p<0.01) and significant (p<0.05) difference on canopy diameter respectively. While days to 50% flowering was highly significantly (p<0.01) influenced by interaction effect of cultivars and NPSZn + urea. Number of primary and secondary branches were highly significantly (p<0.01) affected by the main effect of cultivars and NPSZn + urea respectively. The highest (2.24 t ha^{-1}) and the lowest (1.46 t ha^{-1}) total dry pod yield were obtained at the combined effect of Melka Shote with 84.5NPSZn+136.5 urea kg ha^{-1} and with the control respectively. It is suggested to repeat the study to come up with sound recommendation suitable for the area.

Keywords: cultivars, interaction, Melka Awaze, Melka shote, urea

1. Introduction

Hot pepper (*Capsicum annuum* L.) is one of the *Capsicum spp.* dominates world spice trade; while, sweet pepper has become a popular vegetable and cash crop in the tropics for smallholders (Lin *et al.*, 2013) [38]. In many areas, pepper is grown predominantly as monocrop and rotated with cereals or legumes, during the main rainy season. However, pockets of production in the dry season using irrigation also found, particularly in the rift valley of Ethiopia (Getahun and Habtie, 2017) [26]. Hot pepper has not only attained economical, but also traditional importance. It is also important in the local dishes as green pod, fine powder from the dry fruits of hot pepper, grinded mature green fruits blended with other spices (Getahun and Habtie, 2017) [26].

Despite tremendous importance of pepper as vegetable, spice, medicine and ornamental, the production and productivity of hot pepper is low in Ethiopia as compared to world production and productivitiey. Evidently, FAO, (2016) reported that world dry chilies and peppers coved an area of 1.8 million ha with total production of 3.9 million tonnes. While, green chilies and peppers occupied total area of 1.9 million ha and total production from this harvested area is 34.5 million tonnes. In terms of productivity, dry chilies and peppers produced yield ha^{-1} of 2.2 tonnes and that of green chilies and peppers 17.8 tonnes ha^{-1}. In case of Ethiopia, CSA (2017) [17] reported, green and red pepper covers an area of 190,533.74 hectare which shares about 79.5% of the total area occupied by vegetable crops (239,609.76 hectares). In terms of production, green and red peppers share 48.2% of vegetable production whereby 391,598.6 tonnes of both peppers produced at the national level with yield per hectare of 1.83 and 6.3 t ha^{-1}

for red and green peppers respectively.
The average output ha^{-1} for green and red dry pod is low as compared to that of world average production productivity. This could be due to one or more of the different productivities limiting factors including shortages of improved cultivars, inadequate seed production and promotion, poor extension works, susceptibility of released cultivars to diseases, poor agronomic practices (plant population, irrigation amount and frequencies, fertilizer type and level) across location and seasons with corresponding cultivars (Fekadu and Dandena, 2006; Shumeta, 2012; Getahun and Habtie, 2017) [23, 52, 26]. To solve these problems, only some research activities like adaptation trial on hot pepper (Gebremeskel *et al.*, 2015) [25], plant population (intra and inter row spacing) for a single season and at one location, DAP and urea rates (Teka, personal communication, 2017) have been undertaken.
However, there are huge research gaps in all horticultural, cereals and other crops in terms of cultivar development, crop water requirement, planting time, plant population for different season and location, fertilizer level for each crop. Particularly in Raya valley, hot pepper is a major spice and vegetable crop produced by the majority of farmers. It is one among the vegetable crops on which there was no recommendation of full necessary agronomic practices like plant population ha^{-1}, amount and frequency of irrigation and blended fertilizer rate studies have not been undertaken. Therefore, to help the producers achieve sustainable production and improve their livelihood, it is very important to promote best adaptable and high yielding cultivars along with optimum rate of blended fertilizer are the issues must come up first.
Thus, this work is initiated with the objectives to

- ✓ Determine the response of two hot pepper cultivars to different levels of blended NPSZn and urea fertilizers for growth and yield,
- ✓ To determine optimum rate of NPSZn for selected hot pepper cultivars
- ✓ Assess a possible interaction effect of cultivars and rate of blended fertilizer on growth and yield of hot pepper.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was carried out at MhARC, under irrigation condition. The center is situated at about 678 km to the north of the capital, Addis Ababa, in Raya Azebo southern Tigray zone. As metrological class of the center indicated, geographically the area is located at 12° 41' 50" North latitude and 39° 42' 08" East longitude with an altitude of 1578 m.a.s.l. The site receives mean annual rainfall of 750 mm. The average minimum and maximum temperature of the site is 18 and 25 °C, respectively. The soil textural class of the experimental area is clay loam with pH of 7.9.

2.2. Treatment and Eexperimental Design

The experiment consisted of five blended (N-P_2O_5-S-Zn) + urea fertilizer rates, one without fertilizer as control and two selected hot pepper cultivars (Table 1). For a reference of N-P_2O_5-S-Zn which have percentage composition of 17.7N-35.3P_2O_5+6.5S+2.5Zn, the blanket recommendation of Urea and DAP for hot pepper production at Raya Azebo was used. The blanket recommendation of N and P at Raya Azebo was 60 kg ha^{-1} (130.4 kg Urea ha^{-1}) and 10 kg ha^{-1} (22.9 kg P_2O_5) respectively (Teka, personal communication, 2017). So, apply 22.9 kg ha^{-1} of P_2O_5 in the form of NPSZn, 65 NPSZn kg ha^{-1} is required. When 65 NPSZn kg ha^{-1} applied, 11.5 kg ha^{-1} of N was applied concurrently; thus, to apply the recommended N (60 kg ha^{-1}) in parallel with NPSZn, 48.5 N is left. So, the remaining N was applied in the form of urea which is 105 kg ha^{-1}. Accordingly, 65kg of NPSZn and 105 kg of Urea ha^{-1} were used as the reference. The rest levels of NPSZn + urea was arranged by adding and subtracting 30% and 60% of the rate used as a reference (Table 2). Of the total N intended to be applied in the form of urea, 30.8% of each rate which are (13.2, 22.6, 32.3, 42 and 51.7 kg for 42.8, 73.5, 105, 136 and 168 kg of urea, respectively) were applied at transplanting with NPSZn and the rest was applied at 45 days from transplanting. The treatments were laid down in randomized complete block design (RCBD) with factorial arrangement (2 *6 = 12) with three replications.

2.2.1 Planting material

Two commercial cultivars of hot pepper namely Melka Shote and Melka Awaze were introduced from Melkassa Agricultural Research Center (MARC) on the basis of adaptation trial conducted on different hot pepper cultivars (Melka Shote, Mareko Fana, Melka Zala and Melka Awaze) at Raya valley. From the trial, both Melka Shote and Melka Awaze cultivar was recommended for the farmers at that location (Gebremeskel *et al.*, 2015) [25].

Table 1: Description of treatment combinations of blended fertilizer with pepper cultivars

No.	Treatments		Nutrients concentration			
	Cultivars	Fertilizer NPSZn Kg/ha	N	P_2O_5	S	Zn
1	MA	0	0	0	0	0
2		26 NPSZn + 42.8 Urea	24	9	1.7	0.65
3		45.5 NPSZn + 73.5 Urea	42	16	3	1.13
4		65 NPSZn + 105 Urea	60	23	4.2	1.63
5		84.5 NPSZn +136.5 Urea	78	30	5.3	2.11
6		104 NPSZn + 168 Urea	96	37	6.7	2.6
7	MS	0	0	0	0	0
8		26 NPSZn + 42.8 Urea	24	9	1.7	0.65
9		45.5 NPSZn + 73.5 Urea	42	16	3	1.13
10		65 NPSZn + 105 Urea	60	23	4.2	1.63
11		84.5 NPSZn +136.5 Urea	78	30	5.3	2.11
12		104 NPSZn + 168 Urea	96	37	6.7	2.6

MA = Melka Awaze, MS = Melka Shote

2.3. Data Collected
2.3.1. Growth and phenological variables
Growth, phenological, yield components and yield data like plant height (cm), above ground total biological dry weight plant^{-1} (g), days to 50% flowering, days to first harvest, number of fruits plant^{-1}, marketable, unmarketable and total dry pod yield (t ha^{-1}), pod length and width (cm) were collected from sampled plants.

2.3.1.1. Total leaf area (TLA cm^2): It was determined from five randomly taken plants at complete pod setting and the mean value of them were taken. TLA was obtained by measuring the length and width of five leaves for each five plants and counting the total number of leaves with respect to the plant. The leaf area was calculated and then multiplied by respective plant's total number of leaves to obtain the total leaf area using the formula developed by Swart *et al*. (2004) [57]:

LA= LL x LW x 0.69

TLA = LA x TNL Where: LA = Leaf area, LL= Leaf length, LW= Leaf width and

TNL = Total number of leaves

2.3.1.2. Leaf area index (LAI): Leaf area index refers to ground covered by the leaf. It was calculated from five randomly taken plants using the formula suggested by Sestak *et al.* (1971) [49] and the average value was taken.

Leaf area index (LAI) = Leaf area in (cm^2)/Land area in cm^2

2.4. Data Analysis
The collected growth, phenological, yield components, yield and physical pod quality data were subjected to analysis of variance using SAS software version 9.3. Significant treatment differences were separated using the Least Significant Difference (LSD) test at the alpha level of 5%.

3. Results and Discussion
3.1. Growth and Phenological Response
3.1.1. Plant height
Plant height was significantly ($p<0.05$) affected by the interaction effect of cultivar and fertilizer rates (NPSZn + urea). It also highly significantly ($p < 0.01$) influenced by the main effect of both cultivars and NPSZn + urea. The tallest plant height (61.27 cm) was recorded from combination of Melka Awaze cultivar with 104 kg ha^{-1} NPSZn + 168 kg ha^{-1} urea. While the shortest (36 cm) was recorded by interaction of Melka Shote with control (0NPSZn + urea kg ha^{-1}) (Table 2). This might be attributed to the function of genetic characteristics, response or adaptability of cultivars to the environment and fertilizer rates.

Increasing in plant height while NPSZn + urea rate increased might be attributed to nitrogen which is component of amino acids and chlorophyll which is the primary light harvesting pigm ent for photosynthesis (Bhuvaneswari *et al*., 2014). Zn has also a great role in increasing length of internode (elongates plant height) and protein synthesis (Marschner, 1995; Cakmak, 2000) [40, 15] thereby plant height. Hassaneen (1992) [31] found sulfur application plays a great role as a soil amendment to improve the availability of nutrients such as P, K, Zn, Mn and Cu which in turn enhance plant growth. In line with this, Bhuvaneswari *et al*. (2014) reported application of N fertilizer at the levels of 100 and 150 kg N ha^{-1} produced the tallest plant. Aminifard *et al*. (2012) [7] reported the highest plant height (41.67 cm) at reproductive stage was recorded by cultivar received 150 kg N ha^{-1}. Wahocho *et al*. (2016) [61] revealed growth characters of chilies were significantly affected by N levels and cultivars whereby the interaction effect of 250 kg N ha^{-1} and Longi cultivar showed maximum plant height.

3.1.2. Total leaf area and leaf area index
Total leaf area (TLA) was significantly ($p<0.05$) affected by the combined effect of cultivars and fertilizer doses. Similarly, it also significantly ($p<0.05$) influenced by the main effect of cultivars and highly significantly ($p<0.01$) by the rates of NPSZn + urea. While, LAI was affected significantly ($p<0.05$) by interaction effect of both main factors. The main effect of cultivars and fertilizer (NPSZn + urea) rates exerted highly significant ($p<0.01$) difference on LAI. Thus, the mean maximum TLA (9184.4 cm^2) was recorded when Melka Shote cultivar combined with 104 NPSZn + 168 urea kg ha^{-1}. This, is statistically at par with the interaction effect of both Melka Awaze and Melka Shote cultivars with 84.5 NPSZn + 136.5 urea kg ha^{-1} and Melka Awaze with 104 NPSZn + 168 urea kg ha^{-1} with corresponding mean value of 8975.3 cm^2, 8775.8 cm^2 and 7797.1 cm^2. While the lowest value (4321.1 cm^2) was obtained when Melka Awaze cultivar kept unfertilized (Table 2). Similarly, LAI was significantly influenced by the interaction effect of cultivars and NPSZn + urea rates in which the maximum value (5.57) was recorded when Melka Shote was combined with 104 NPSZn + 168 urea kg ha^{-1}. Whereas the lowest LAI (2.25) was recorded from the interaction of Melka Shote with the control (0kg NPSZn + urea kg ha^{-1}) (Table 2).

Number of leaves and LAI were significantly affected by N rates whereby an increase in N promotes cell division and branching which in turn increases TLA and LAI (Simon and Tesfaye, 2014) [53]. S has a great role in the formation of amino acids methionine (21% S) and cysteine (27% S), synthesis chlorophyll (enhance the process of photosynthesis) thereby plant growth and development (Jamal, 2009) [33]. Zinc is essential element for crop production and required for carbonic enzyme synthesis, present in all photosynthetic tissues and required for chlorophyll biosynthesis (Ali *et al*., 2008; Mousavi, 2011) [4, 45]. In accord to this, cultivars differed significantly in number of leaves in which the cultivar Melka Shote gave the highest number of leaves plant^{-1} (Simon and Tesfaye, 2014) [53]. The highest total number of leaves recorded at the highest rates of nutrients, particularly nitrogen (Mebratu, 2014 [43]; Ayodele *et al*., 2015) [10] which directly implies the largest TLA and LAI.

3.1.3. Above ground total dry biomass
Above ground total dry biomass was significantly ($p<0.05$) influenced by interaction effect of cultivars and NPSZn + urea rates. It also highly significantly ($p<0.01$) influenced by main effect of fertilizer (NPSZn + urea) rates. However, it was not affected significantly ($p \geq 0.05$) by cultivars (Appendix Table 1). The highest (121.13 g) and the lowest (65.13 g) total dry biomass were recorded at the combination of Melka Shote with 84.5 NPSZn + urea kg ha^{-1} and control respectively (Table 2). In case of main effect of fertilizer rates, the maximum total dry biomass (119.17 g) was recorded from the cultivars treated with 84.5NPSZn + urea kg ha^{-1}. While the lowest (71.58 g) was recorded from the control.

Table 2: Interaction effect of cultivars and fertilizer rates on plant height, canopy diameter, total leaf area, leaf area index and above ground total dry biomass

Treatments		Vegetative Growth characters			
Cltv	NPSZn + urea kg ha-1	PH (cm)	TLA (cm^2)	LAI	AGTDB (g)
MA	0	49.20^{ab}	4321.10^{f}	2.51^{ef}	78.03^{fg}
	26/42.8	57.27^{ab}	6024.30^{cdef}	2.65^{def}	76.23^{gh}
	45.5/73.5	50.53^{ab}	4555.10^{f}	2.87^{cdef}	94.30^{de}
	65/105	57.13^{ab}	6754.60^{cde}	3.5^{bcde}	96.60^{cd}
	84.5/136.5	57.47^{ab}	8975.30^{ab}	3.83^{bc}	117.10^{ab}
	104/168	61.27^{a}	7797.10^{abc}	3.33^{bcde}	107.90^{bc}
MS	0	36.00^{c}	5143.00^{ef}	2.25^{f}	65.13^{h}
	26/42.8	46.13^{bc}	5338.20^{def}	2.81^{cdef}	87.70^{defg}
	45.5/73.5	57.13^{ab}	7042.20^{bcde}	3.58^{bcd}	82.60^{efg}
	65/105	54.20^{ab}	7258.60^{abcd}	3.93^{b}	89..28^{def}
	84.5/136.5	54.47^{ab}	8775.80^{ab}	4.16^{b}	121.13^{a}
	104/168	55.27^{ab}	9184.30^{a}	5.57^{a}	93.60^{de}
LSD (0.05)		12.13	2003.9	1.02	12.79
CV(%)		8.72	12.13	16.43	8.43

Means within columns followed by different letter (s) for each variable are significantly different *($p<0.05$)*
Cltv = Cultivars, MA = Melka Awaze, MS = Melka Shote, PH = Plant height in cm, TLA = Total leaf area in cm^2, LAI = Leaf area index, AGTDB = Above ground total dry biomass.

The concentration range of N, P, S and Zn in dried plant tissues from the absorbed nutrient concentration accounts for 1-5%, 0.1 – 0.5 %, 0.1 – 0.4% and 25 – 150 ppm respectively (Jones and Olson-Rutz, 2016). Moreover, total biomass was positively responded to NP rates whereby the maximum value was recorded from the application of 92/69 NP_2O_5. While the least biomass was recorded from unfertilized experimental units (Wossen, 2017). Kryzanowski (2005) [62, 36] reported that P is abundant in the actively growing tissue and about 25 % of their total dry weight. In line with this finding, the maximum dry biomass yield was obtained from cultivars which received 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} (Tesfaw *et al*., 2013) [58]. By this author, the minimum dry biomass yield was recorded on Melka Zala with fertilizer levels of 0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}. Application of nitrogen increased total biological dry mass compared to the control (Mebratu, 2014) [43].

3.1.4. Days to 50% flowering

Days to 50% flowering was highly significantly (*$p<0.01$*) affected by interaction of cultivars and fertilizer (NPSZn + urea) rates. The main effect of NPSZn + urea exerted highly significant (*$p<0.01$*) difference on days to 50% flowering; It also, significantly (*$p<0.05$*) affected by cultivars. Result indicated, the combination of Melka Awaze cultivar 104 NPSZn + 168 urea kg ha^{-1} and 84.5 NPSZn + 136.5 urea kg ha^{-1} prolonged day to 50% flowering (both 99.33 days). In contrast, Melka Awaze cultivar flowered earlier when interacted with plots not received fertilizer which in average took 87 days to commence flowering as illustrated in (Table 3).

Guohua *et al*. (2001) [28] and Simon and Tesfaye (2014) [53] found that blooming was inhibited with fertilizer containing highest level of N and micro nutrient particularly Fe and Zn supply due to transformation of assimilates towards vegetative growth rather than reproductive growth. Tesfaw *et al*. (2013) [58] reported coming to flowering stage of vegetable crops are linked to genetic factors, nutrient rates and temperature. Also, Alemayehu and Jemberie (2018) [3] reported increasing NPS fertilizer rates delayed days of potato flowering. Uchida (2000) [60] revealed that nitrogen and phosphorous deficiency causes early stunted flowering in some crops, which results in a significant reduction in yield and quality latter on.

Variation in 50% days to flowering attributed to not only the individual action of nutrients and cultivars but also the interaction of them. Thus, increasing the rates of NPSZn + urea prolonged the number of days required to bloom due to parallel increment of nitrogen. While, plants not fertilized with NPSZn + urea faced stunted vegetative growth and accelerate the flowering which is not strong enough (forced flowering) to occur. This latter on produce small sized pods which are not physically attractive and latter on increases unmarketable yield In accord to this, Mebratu (2014) [43]; Delelegn (2011) [20]; Aminifard *et al*. (2012) [7] revealed, days to flowering and maturity are influenced by interactive effect of fertilizer level, cultivar and environment. Also, Wahocho *et al*. (2016) [61] found, the maximum number of days to commence flowering were observed in Kunri 1 cultivar at N level of 250 kg ha^{-1}; although, the minimum days to flower initiation was recorded from Nagina at 0 kg N level.

3.1.5. Days to first harvest

Days to first harvest was significantly (*$p<0.05$*) influenced by interaction effect of cultivars and fertilizer rates (NPSZn + urea). While, it was highly significantly *($p<0.01$)* affected by both main effect of cultivars and NPSZn + urea rates. The interaction of Melka Shote with the control significantly delayed days to first harvest (177.33 days). Which is significantly at par with the combination of Melka Shote with both 104 NPSZn + 168 urea kg ha^{-1} (175.67 days) and 84.5 NPSZn + 136.5 urea kg ha^{-1} (173.67 days) and Melka Awaze with the control fertilizer (173.33 days). While the interaction of Melka Awaze cultivar with 45.5 NPSZn + 73.5 urea kg ha^{-1} shortened days to first harvest (159.67 days) which is statistically similar with the combination of Melka Awaze with 65NPSZn + 105 urea kg ha^{-1} (Table 3).

Phosphorus is a crucial nutrient involved in stimulating and enhancing bud development and seed formation so that application of P quickens maturity of fruits and seed (Kelly, 2009) [35]. However, as phosphorous aids root development, flower initiation, seed and fruit development, lack of P delayed maturity and poor seed and fruit development (Uchida, 2000) [60]. Nitrogen deficiency causes stunted growth and decrease fruit number and size; whereas high nitrogen level can stimulate excessive vegetative growth which can delay fruit setting and maturation (Sainju *et al*., 2003) [48]. Also, zinc plays an important role in seed development and zinc-deficient plants show delayed maturity (Shukla *et al*., 2009) [51].

Both unfertilized plots and those fertilized with the highest rate of NPSZn + urea prolonged (delayed) days to first harvest of red pods. This might have attributed to the rationale that optimum amount of P accelerates pods maturity; to the opposite its deficiency causes stunted early flowering; but, delays the maturity of pods and coming to red bright color. On the other hand, continuous increment of N rate diverts photo assimilate to wards vegetative growth and prolongs the maturity of pods. To the opposite, shortage of nitrogen causes stunted plant growth and earlier flowering and pod setting. However, the pods stay green and unmatured due to shortage of photo assimilate for a longer period of time.

This finding agrees with some previous research findings. Increasing levels of N delayed the period require for fruit setting and fruit ripening (Manoj *et al*., 2013) [39]. Alemayehu and Jemberie (2018) [3] reported increasing of NPS fertilizer level increased days to maturity of potato cultivars in the way that as NPS fertilizer increased, duration of vegetative phase of potato also prolonged and in turn maturity date delayed. Bosland and Votava (2012) [14] indicated that, N is critical for pepper growth, but too much N can overstimulate vegetative growth, thus it results large and succulent late maturing plants.

3.2. Yield components and Yield

3.2.1. Number of pods plant

Number of pods plant^{-1} were significantly ($p<0.05$) affected by interaction effect of fertilizer rate (NPSZn + urea) and cultivars. This character was also highly significantly ($P<0.01$) affected by main effect of cultivars and NPSZn + urea rates. The highest average number of pods plant^{-1} (43.47) was recorded when Melka Shote interacted with 84.5 NPSZn +136.5 urea kg ha^{-1}. It is statistically at par with combination of Melka Shote cultivar with 65 NPSZn + 105 urea kg ha^{-1}, 45.5 NPSZn + 73.5 urea kg ha^{-1}, Melka Awaze with 84.5 NPSZn +136.5 urea kg ha^{-1} and Melka Shote with 104 NPSZn + 168 urea kg ha^{-1} with corresponding pod numbers of 41.53, 39.4, 36.4 and 35.1. While, the lowest number of pods plant^{-1} (23.77) recorded from the interaction of Melka Awaze with control (0 kg ha^{-1}) which had no significant variation when the same cultivar combined with 104NPSZn + 168 urea kg ha^{-1}, Melka Shote combined with the control and 26 NPSZn + 42.8 urea kg ha^{-1} with pod number of 27.67, 24.6 and 33.1, respectively (Table 3).

Regardless of the quantity of pod numbers, NPSZn + urea positively increased pod number plant^{-1} in both cultivars up to a certain level. This might be due to the contribution of each nutrients in NPSZn fertilizer for balancing the growth of vegetative (root, stem and branches) and reproductive parts at the optimum rate. Beyond this level, NPSZn + urea enhances vegetative growth at the expense of reproductive growth. Thus, it reduces pod number plant^{-1} and yield per unit area. N enhances rapid growth, increases leaf size and promotes fruit and seed development (Tucker, 1999) [59]. Zinc in the plant increases cell differentiation; the greater the cell differentiates the larger and denser the number of fruit (Anonyms, 2002). In line with this, Tesfaw *et al.* (2013) [58] reported fruit numbers plant^{-1} were statistically differed due to cultivars, N and P; whereby the highest average number of pods plant^{-1} were obtained from the plots received 92 kg ha^{-1} of N and 138 kg ha^{-1} P_2O_5; but it varies with cultivar. Mebratu *et al.* (2014) [43]; Simon and Tesfaye (2014) [53]; Ayodele *et al. (*2015) [10]; Wahocho *et al*. (2016) [61] found that N rates revealed positive association with pod numbers plant^{-1}.

3.2.2. Marketable dry pod yield

Marketable dry pod yield (t ha^{-1}) was significantly ($p<0.05$) affected by the interaction of fertilizer rates (NPSZn + urea) and cultivars. Similarly, it was highly significantly ($p<0.01$) influenced by main effect of fertilizer rates (NPSZn + urea) and cultivars (Appendix Table 3). The maximum and significantly different marketable dry pod yield (2.29 tha^{-1}) was noted when Melka Shote cultivar combined with 84.5 NPSZn +136.5 urea kg ha^{-1}. While the lowest (1.28 t ha^{-1}) was recorded when Melka Awaze kept unfertilized (control) (Table 3). This could be strongly linked to yield components like pod length, pod width, higher seed weight and total dry pod weight plant^{-1}.

Deficiency of N resulted in stunted growth, appearances of chlorosis and red and purple spots on the leaves, restrict lateral bud growth (from which leaves, stem and branches develop) (Bianco *et al*., 2015) [11]. However, at the optimum rate which varies with cultivar, season and soil, N accelerates photosynthetic processes; leaf area production as well as net assimilation rate (Ahmad *et al.*, 2009) [1] which are determinant of crop yields (Rafiq *et al*., 2010) [47]. P is needed for photo-assimilate metabolism, sugar and starch formation, energy transfer and movement of carbohydrates. Thus, it contributes for yield ascending by providing and storing sufficient food for the plants (Hamza, 2008) [29].

Sulphur helps the uptake of N, P, K and Zn by the plant and increases crop productivity and quality (Zhang *et al*., 1999) [65]. Increasing yield at relatively higher rates of Zn may be due to the contribution of Zn in protein synthesis and energy production, carbohydrate and lipid metabolisms which in turn helps to increases the yield and quality of vegetable crops (Hansch and Mendel, 2009) [30]. Application of fertilizers containing sufficient Zn increases performance and quality of crops (Alloway, 2008) [6] as Activity of RuBP, carboxylase enzyme, Photosystem II, ATP synthesis and chloroplasts activity influenced by Zn. In agreement to this, Mebratu *et al*. (2014) [43] reported the highest marketable yield was obtained at 100 kg N ha^{-1}. Furthermore, plants sprayed with both Zn and B or Zn alone showed maximum pod diameter, pod length and individual fruit weight hot pepper (Sultana *et al*., 2016) [56].

3.2.3. Unmarketable dry pod yield

The interaction of cultivars and fertilizers rates had exerted significant ($p<0.05$) difference on unmarketable dry pod yield. It also influenced highly significantly ($p <0.01$) by the main effect of NPSZn + urea rates. Statistically the highest unmarketable dry pod yield (0.20 t ha^{-1}) was observed by the interaction of Melka Awaze with 0 kg ha^{-1} of NPSZn + urea kg ha^{-1} followed by the interaction of this cultivar with 104 NPSZn + 168 urea (0.19 t ha^{-1}) and Melka Shote with 84.5 NPSZn +136.5 urea kg ha^{-1} (0.15 t ha^{-1}) (Table 6). In this case, the highest unmarketable yield obtained at the control could be attributed to lack of nutrients leading to weak growth of the plant and smaller pod size. The highest level of NPSZn + urea enhanced vegetative growth (due to N in this rate) which in turn increases unmarketable yield.

Lack of phosphorous prolonged maturity and poor seed and fruit development (Uchida, 2000) [60]. Also, shortage of Zn decreased the performance and quality of crop due to decline in plant photosynthesis and destroy RNA, amount of carbohydrates and synthesis of protein (Mousavi *et al*., 2007; Efe and Yarpuz, 2011) [46, 21]. Similarly, excessive N lead to growth of more branches, increased plant height which could have increased competition for assimilate partitioning among the plant parts and reduces pod length and width and increases unmarketable yield of hot pepper cultivars (Mebratu *et al*., 2014) [43]. Ghaffoor *et al*. (2003) [27] reported that unfertilized cultivar gave maximum unmarketable yield. Moreover, Nigussi *et al*. (2017) reported the highest unmarketable yield obtained from the control treatment.

3.2.4. Total dry pod yield
Total dry pod yield was affected significantly *($p<0.05$)* by the interaction effect of both factors and by the main effect of cultivars. It also highly significantly ($p<0.01$) influenced by the main effect of fertilizer rates (NPSZn + urea). The highest mean value of total yield ha^{-1} (2.44 t ha^{-1}) was recorded at the interaction of Melka Shote with 84.5 NPSZn +136.5 urea kg ha^{-1} rate. While the lowest total yield ha^{-1} (1.46 t ha^{-1}) was noted when Melka Shote cultivar received no nutrient (Table 3). The highest total yield might be attributed to the production of more number of pods having marketable size which is probably the function of supplied nutrients and genetic make-up of the cultivars.

This might be attributed to P which promote a strong stem growth, producing large number of flower and contribute for increasing the number of fruits (Fandi *et al*., 2010) [22]. In similar way, Sainju *et al*. (2003) [48] reported that phosphorous has a positive role in stimulating healthy root growth which helps in better utilization of water and nutrients. In opposite, Zekri and Obreza (2003) [63] stated that lower concentrations of N, P and K limit plant growth, flower and fruit production due to their effects on photosynthesis and carbohydrate synthesis. In accord to this, yield and quality of pepper are greatly improved through application of N and P (Baghour *et al*. 2001). Increasing P level increased pod yield of hot pepper cultivar (Simon and Tesfaye, 2014) [53]. Tesfaw *et al*. (2013) [58] reported that cultivars treated with 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} produced the highest total dry pod yield.

Table 3: Interaction effect of cultivar with fertilizer rates on days to 50 % flowering, days to first harvest, number of pods plant^{-1}, marketable, unmarketable and total dry pod yield

Treatment		Phenological, yield components and Yield parameters						
Cultivars	**NPSZn/urea (kg ha^{-1})**	**DT 50%F**	**DTFH**	**NPPP**	**MDPY (t ha^{-1})**	**UDPY (t ha^{-1})**	**TDPY (t ha^{-1})**	**Pod length (cm)**
MA	0	87.00^{f}	173.33^{abc}	23.77^{f}	1.28^{f}	0.20^{a}	1.48^{e}	8.1^{f}
	26/42.8	90.33^{edf}	170.33^{bcd}	33.53^{bcde}	1.50^{ef}	0.13^{c}	1.64^{de}	8.6^{def}
	45.5/73.5	94.33^{bcd}	159.67^{f}	28.03^{def}	1.85^{bcd}	0.11	1.96^{bc}	10.7^{ab}
	65/105	94.33^{bcd}	162.00^{ef}	31.67^{cdef}	2.02^{b}	0.11^{c}	2.13^{b}	10.99^{a}
	84.5/136.5	99.33^{a}	167.33^{de}	36.40^{abcd}	1.93^{bc}	0.13^{c}	2.06^{bc}	8.8^{def}
	104/168	99.33^{a}	169.00^{cd}	27.67^{def}	1.65^{de}	0.19^{ab}	1.83^{cd}	8.7^{def}
MS	0	90.33^{def}	177.33^{a}	24.60^{ef}	1.33^{ef}	0.13^{c}	1.46^{e}	8.6^{ef}
	26/42.8	91.33^{def}	166.67^{de}	33.10^{bcdef}	1.73^{cde}	0.12^{c}	1.85^{bcd}	10.1^{abcd}
	45.5/73.5	89.00^{ef}	170.00^{bcd}	39.40^{abc}	1.89^{bcd}	0.12^{c}	2.01^{bc}	9.97^{abcde}
	65/105	92.33^{cde}	167.00^{de}	41.53^{ab}	1.90^{bcd}	0.13^{c}	2.03^{bc}	9.1^{cdef}
	84.5/136.5	97.00^{abc}	173.67^{abc}	43.47^{a}	2.29^{a}	0.15^{abc}	2.44^{a}	10.4^{abc}
	104/168	97.33^{ab}	175.67^{ab}	35.10^{abcd}	1.85^{bcd}	0.14^{bc}	1.99^{bc}	9.5^{bcdef}
LSD (0.05)		4.72	5.87	9.46	0.27	0.05	0.30	1.5
CV (%)		1.49	2.03	9.49	7.69	17.7	7.56	9.3

Means within columns for each variable followed by different letters are statistically different from each other at ($p<0.05$).
MA = Melka Awaze, MS = Melka Shote, DT 50%F = Days to fifty percent flowering, DTFH = Days to first harvest, NPPP = Number of pods plant^{-1}, MDPY = Marketable dry pod yield, UDPY = Unmarketable dry pod yield, TDPY = Tot al dry pod yield

4. Summary and Conclusions
The finding showed, plant height, days to first harvest, total leaf area, leaf area index, number of pods plant^{-1}, dry pod yield (marketable, unmarketable and total) and pod length were significantly ($p<0.05$) influenced by interaction effect of cultivars and NPSZn + urea. The main effect of cultivars and NPSZn + urea exerted highly significant *($p<0.01$)* and significant ($p<0.05$) difference on canopy diameter respectively. While days to 50% flowering, number of primary and secondary branches were highly significantly ($p<0.01$) influenced by interaction effect of cultivars and NPSZn + urea, main effect of cultivars and NPSZn + urea respectively.

The highest marketable (2.29 t ha^{1}) and total dry pod yield (2.44t ha^{-1}) were recorded when Melka Shote cultivar was combined with 84.5 NPSZn +136.5 urea kg ha^{-1}. Whereas, the lowest marketable (1.28 t ha^{-1}) and total dry pod yield (1.46 t ha^{-1}) were recorded from the interaction of Melka Awaze with control (0 kg ha^{-1}). So, to achieve more yield, the producers can use the Melka Shote cultivar with 84.5 NPSZn +136.5 urea kg ha^{-1} rate of fertilizer, in the case when this cultivar is not available it is possible to use Melka Awaze cultivar with 65 NPSZn + 105 urea kg ha^{-1} which gave total dry pod yield of 2.13 t ha^{-1}

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