Performance of hybrid maize (Zea mays L.) influenced by planting density and tillage system

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ABSTRACT

A field experiment on “Performance of maize hybrids as influenced by establishment methods and planting density” was accomplished at research farm of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal during rabi season of 2015/16. The experiment was laid out in strip-split plot design with three replications consisting of two hybrids as horizontal factor (Rampur hybrid 4 and Rampur hybrid 6), two tillage methods as vertical factors (zero and conventional tillage) and four plant populations as sub-sub plot factors (55.555, 69.444, 85.470 and 1.01.010 plants ha⁻¹). Both maize hybrids (Rampur hybrid 4 and Rampur hybrid 6) produced similar grain yield (5.88 and 6.11 t ha⁻¹, respectively). Similarly, both tillage methods i.e. zero and conventional tillage also produced similar grain yield (6.25 t ha⁻¹ and 5.74 t ha⁻¹, respectively). Beside this, the plant population showed significant effect on grain yield of maize hybrids. Significantly higher grain yield (6.54 t ha⁻¹) was obtained from the population of 85.470 plants ha⁻¹ than 55.555 (5.31 t ha⁻¹) and 69.444 (5.92 t ha⁻¹) plants ha⁻¹ but remained at par with 1.01.010 plants ha⁻¹ (6.21 t ha⁻¹). Both hybrid does not differ statistically in respect to grain yield due to tillage method but produce higher yield at higher planting density than low planting density.

Keywords: Crop geometry, establishment method, phenology, plant population, yield attributes

INTRODUCTION

Maize rank second position in terms of area, production and productivity after rice in Nepal (MOAD 2015; Kandel et al. 2018). It is cultivated in 0.92 million hectares of lands with the production and productivity of 2.28 million metric tonnes and 2.46 t ha⁻¹, respectively (MOAD 2015). Maize occupies 30.04% of total cultivated agricultural land and shares about 23.87% of the total cereal production of Nepal (MOAD 2015). In Nepal, maize demand has been constantly growing by about 5% annually in the last decades (Sapkota and Pokhrel 2013) and per capita maize consumption in Nepal is 98 g/person/day (Ranum et al. 2014). Hybrid maize for example, about 85% more grain yield was obtained from Gaurav in comparison to OPV Hill Pool White (Adhikari et al. 2004). In this context, Koirala (2002) and Pathik (2002) had emphasized for the production of hybrid maize in commercial scale which will assist to increase national economic growth. Thus, growth of hybrid maize cultivation can be considered as a viable option to meet the need of industries and for food security in hills of Nepal. Further, the cost of crop production is becoming higher due to higher cost of inputs and labour in Nepal. Therefore, it is also essential to evaluate hybrid maize performance under different tillage practices. Labios et al. (1997) reported that tillage practices contribute to labour cost in any crop production system resulting to the lower economic returns. In this context, growing of maize under conservation (zero) tillage can be one of the best options to make the maize production economically more attractive zero and minimum tillage may be introduced to offset the production cost and other constraints associated with environment and socio-economic conditions (Jat et al. 2006). So, people are now giving more emphasis to adopt zero tillage practice (Bhatt et al. 2004; Khattak et al. 2004).

Plant density in other hand affect the growth and yield attributes of the member of grass family (Vega et al. 2001). Maize yield varies with varying
plant density (Luque et al. 2006). Due to difference in genetic potential, maize yield differs significantly under varying planting density. Liu et al. (2004). Therefore, the present research was conducted to evaluate the response of different maize hybrids to different plant population under different tillage systems for maximizing grain yields during winter season of 2015/16 at NMRP, Rampur, Nepal.

MATERIALS AND METHODS

Experiment details

A field experiment was conducted at the research block of NMRP, Rampur, Chitwan, Nepal from October, 2015 to March, 2016. The experimental site is located at 27° 0 37' North latitude and 84° 25' East longitude with an elevation of 225masl (Sharma et al. 2018). The experiment was laid out in strip-split plot design consisting of 16 treatments with three replications. Four different levels of planting geometry (60×30 cm, 60×24 cm, 60×19.5 cm and 60×16.5 cm representing 55.555, 69.444, 85.470 and 1.01.010 plants ha⁻¹ respectively), two released hybrid varieties of maize (Rampur hybrid 4 and Rampur hybrid 6) and two tillage methods (conventional and zero tillage) were used as the treatments. The size of each plot was 6 m×3.6 m. The distance between the replication was 1 m and plots 50 cm. Treatments detail were shown in Table 1.

Inter culture operation

All intercultural operation like thinning, plant protection, weed management, irrigation were followed as per National Maize Research Program (NMRP) recommendation.

Data taken and analysis

All phenological growth stage data as well as yield and yield attributing data were taken from sample row. All collected data were entered in MS excel and analysis of data were carried out by statistical package R.

RESULTS AND DISCUSSION

Emergence (germination)

The emergence of seed was not significantly influenced by hybrids however it was remarkably delayed in Rampur hybrid 6 (6.41 DAS) than Rampur hybrid 4 (5.83 DAS). Similarly, the germination of seed was also not influenced by the method of tillage however, it was remarkably delayed in zero tillage (5.70 DAS) as compared to conventional (5.54 DAS). Shinoto et al. (2019) reported that the number and the percentage of seedlings established were not significantly

Table 1. Treatment combinations of experiment and their abbreviation are given in detail

| Treatment | Notation | Treatment combination |
|-----------|----------|-----------------------|
| T1        | ZTV1D1   | Zero tillage for Rampur hybrid 4 with 55.555 plants ha⁻¹ |
| T2        | ZTV1D2   | Zero tillage for Rampur hybrid 4 with 69.444 plants ha⁻¹ |
| T3        | ZTV1D3   | Zero tillage for Rampur hybrid 4 with 85.470 plants ha⁻¹ |
| T4        | ZTV1D4   | Zero tillage for Rampur hybrid 4 with 1.01.010 plants ha⁻¹ |
| T5        | ZTV2D1   | Zero tillage for Rampur hybrid 6 with 55.555 plants ha⁻¹ |
| T6        | ZTV2D2   | Zero tillage for Rampur hybrid 6 with 69.444 plants ha⁻¹ |
| T7        | ZTV2D3   | Zero tillage for Rampur hybrid 6 with 85.470 plants ha⁻¹ |
| T8        | ZTV2D4   | Zero tillage for Rampur hybrid 6 with 1.01.010 plants ha⁻¹ |
| T9        | CTV1D1   | Conventional tillage for Rampur hybrid 4 with 55.555 plants ha⁻¹ |
| T10       | CTV1D2   | Conventional tillage for Rampur hybrid 4 with 69.444 plants ha⁻¹ |
| T11       | CTV1D3   | Conventional tillage for Rampur hybrid 4 with 85.470 plants ha⁻¹ |
| T12       | CTV1D4   | Conventional tillage for Rampur hybrid 4 with 1.01.010 plants ha⁻¹ |
| T13       | CTV2D1   | Conventional tillage for Rampur hybrid 6 with 55.555 plants ha⁻¹ |
| T14       | CTV2D2   | Conventional tillage for Rampur hybrid 6 with 69.444 plants ha⁻¹ |
| T15       | CTV2D3   | Conventional tillage for Rampur hybrid 6 with 85.470 plants ha⁻¹ |
| T16       | CTV2D4   | Conventional tillage for Rampur hybrid 6 with 1.01.010 plants ha⁻¹ |

Note: ZT Zero tillage; CT Conventional tillage; D1 60 cm×30 cm; D2 60 cm×24 cm, D3 60 cm×19.5 cm; D4 60 cm×16.5 cm
different between the tillage treatments, which was accordance to our result. There was also a non-significant difference between plant populations with respect to the duration needed for the emergence of seedling. The period needed for the emergence of seedling ranged from 5.83 to 6.33 DAS depending upon the plant population. Seed germination was non-significantly early in 55 thousand plants ha\(^{-1}\) (5.83 DAS) as compared to 69 (6.17 DAS), 85 (6.16 DAS) and 101 (6.33 DAS) thousand plants ha\(^{-1}\), shown in table 2.

**Knee high stage**

The knee high stage was not influenced significantly by the maize hybrids and methods of tillage. However, it was remarkably delayed in Rampur hybrid 6 (36.12 DAS) than Rampur hybrid 4 (35.66 DAS) and in conventional (36.0 DAS) than zero (35.79 DAS) tillage. Rampur hybrid 6 took longer duration as compared to Rampur hybrid 4 to attain the knee high stage which was also reflected on physiological maturity stage. This might be the reason for obtaining higher grain yield in Rampur hybrid 6 as compared to Rampur hybrid 4. Further, at the duration needed for the appearance of knee high stage was not influenced significantly by plant population however, it was remarkably delayed in 69 (36.08 DAS) as compared to 55, 85 and 101 thousand plants ha\(^{-1}\) which took the same duration i.e. 35.83 DAS for the appearance of this stage, shown in table 2.

**Tasseling stage**

There was significant difference between hybrids in respect of tasseling stage. Thus, it was significantly delayed in Rampur hybrid 6 (75.71 DAS) than Rampur hybrid 4 (69.83 DAS). Tillage methods did not influence significantly on duration needed for the appearance of the tasseling stage. However, it was remarkably delayed in zero tillage (73.5 DAS) than conventional (72.04 DAS). There was non-significant difference between the plant population with respect to duration needed for the appearance of tasseling stage but it was relatively delayed in 69 (73.33 DAS) as compared to 55 (71.92 DAS), 85 (72.83 DAS) and 101 (73 DAS) thousand plants ha\(^{-1}\), shown in table 2. Non-significant tasseling date due to planting density was earlier reported by Dawadi and Sah (2012) and Rafiq et al. (2010) which is accordance to our findings.

**Silking**

As in tasseling stage, it was significantly delayed in Rampur hybrid 6 (80.58 DAS) as compared to Rampur hybrid 4 (74.96 DAS). On the other hand, the method of tillage did not influence significantly on the appearance of silking stage. However, it was remarkably delayed in zero tillage (78.42 DAS) than conventional (77.12 DAS). Shinito et al. (2019) also reported non-significant appearance of silking due to tillage method, which was accordance to our finding. Further, the difference between plant populations with respect to the duration needed for the appearance of silking stage was found to be insignificant. But relatively, it was delayed in 101 (78.25 DAS) thousand plants ha\(^{-1}\) as compared to other levels (76.83, 78.0 and 78.0 at 55, 69 and 85 thousand plants ha\(^{-1}\), respectively) of plant population. Dawadi and Sah

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**Table 2. Phenological stages of maize hybrids as influenced by tillage methods and plant population during winter season at NMRP, Rampur, Chitwan, Nepal, 2015/16**

| Treatments | Germination | Knee high | Tasseling | Silking | Milking | Dough | Physiological maturity |
|------------|-------------|------------|-----------|---------|---------|-------|------------------------|
| Varieties  |             |            |           |         |         |       |                        |
| Rampur hybrid 4 | 5.83 | 35.66 | 69.83\(^{b}\) | 74.96\(^{b}\) | 116.58\(^{b}\) | 144.12 | 165.46 |
| Rampur hybrid 6 | 6.41 | 36.12 | 75.71\(^{a}\) | 80.58\(^{a}\) | 117.38\(^{a}\) | 145.12 | 166.54 |
| LSD (=0.05) | ns           | ns         | 4.88      | 5.49    | 0.64    | ns    | ns         |
| SEm (±)     | 0.10         | 0.17       | 0.80      | 0.90    | 0.10    | 0.51  | 0.62      |
| Tillage methods |             |            |           |         |         |       |                        |
| ZT          | 5.70         | 35.79      | 73.5      | 78.42   | 119.54  | 144.42 | 166.08 |
| CT          | 5.54         | 36.0       | 72.04     | 77.12   | 120.42  | 144.83 | 165.92 |
| LSD (=0.05) | ns           | ns         | ns        | ns      | ns      | ns    | ns         |
| SEm (±)     | 0.10         | 0.10       | 0.26      | 0.37    | 0.18    | 0.38  | 0.69      |
| Plant population (ha\(^{-1}\)) |            |            |           |         |         |       |                        |
| 55.555      | 5.83         | 35.83      | 71.92     | 76.83   | 116.25  | 143.25\(^{b}\) | 165.5  |
| 69.444      | 6.17         | 36.08      | 73.33     | 78.0    | 116.58  | 143.92\(^{b}\) | 165.67 |
| 85.470      | 6.16         | 35.83      | 72.83     | 78.0    | 117.42  | 145.42\(^{a}\) | 166.33 |
| 101.010     | 6.33         | 35.83      | 73.0      | 78.25   | 117.67  | 145.92\(^{a}\) | 166.5  |
| LSD (=0.05) | ns           | ns         | ns        | ns      | ns      | ns    | ns         |
| SEm (±)     | 0.13         | 0.17       | 0.48      | 0.45    | 0.72    | 0.30  | 0.33      |
| CV, %       | 7.5          | 1.7        | 2.3       | 2.0     | 2.2     | 0.7   | 0.7       |
| Grand mean  | 6.12         | 35.89      | 72.77     | 77.77   | 116.98  | 144.62 | 166.0    |

Means followed by the common letter within each column are not significantly different at 5 % level of significance by DMRT; ns = non-significant, DAS = Days after sowing, ZT= zero tillage, CT=convention tillage
(2012) also reported non-significant appearance in silking date due to planting density, which was accordance to our findings. In contrast Amanullah et al. (2009) reported all the phenological characteristics (vegetative stage, days to tasseling, silking, and maturity), were significantly affected by plant density.

**Milking and dough stage**

Milking stage was recorded significantly early in Rampur hybrid 4 (116.58 DAS) than Rampur hybrid 6 (117.38 DAS). Further, the milking stage was found to be hastened in zero tillage (119.54 DAS) as compared to conventional tillage (120.42 DAS). Lower plant population (55 thousand plants ha$^{-1}$) hastened the milking stage (116.25 DAS) as compared to 69 (116.58 DAS), 85 (117.42 DAS) and 101 (117.67 DAS) thousand plants ha$^{-1}$. It was remarkably delayed in Rampur hybrid 6 (145.12 DAS) than Rampur hybrid 4 (144.12 DAS). Further, the stage was also not influenced significantly by the methods of tillage. However, zero tillage hastened the dough stage (144.42 DAS) as compared to conventional (144.83 DAS). Increase in the level of plant population delayed the appearance of dough stage significantly. Thus, the dough stage was significantly delayed in 101 (145.92 DAS) as compared to 55 (143.25 DAS) and 69 (143.92 DAS) but remained at par with 85 (145.42 DAS) thousand plants ha$^{-1}$. Both lower populations i.e. 55 and 69 thousand plants ha$^{-1}$ were similar but significantly early than 85 thousand plant population with respect to the duration needed for the appearance of dough stage.

**Physiological maturity**

Both the hybrids did not differ significantly in respect of physiological maturity stage. However, its duration was remarkably longer in Rampur hybrid 6 (166.54 DAS) than Rampur hybrid 4 (165.46 DAS). Further, in conventional tillage the physiological maturity stage (165.92 DAS) was recorded early as compared to zero tillage (166.08 DAS). Karki et al. (2015) observed that the duration needed for the appearance of physiological maturity was significantly early in no tillage (130.72 DAS) than conventional tillage (133.83 DAS) in winter season hybrid maize which was lined with our result. There was insignificant difference between different populations regarding the duration needed for the appearance of physiological maturity stage in hybrid maize. The result of the experiment shows that the crop with 55.555 plants ha$^{-1}$ matured in 165.5 DAS and the duration was longer in 69, 85 and 101 thousand plants ha$^{-1}$ (165.67, 166.33 and 166.5 DAS, respectively), shown in table 2. Dawadi and Sah (2012) also reported non-significant appearance in physiological maturity due to planting density, which was accordance to our findings.

**Yield attributing characters**

**Number of cobs per hectare**

The yield attributing characters of hybrid maize presented with table 3, illustrates that the number of cobs harvested from one hectare of land was not influenced by both hybrid varieties and tillage methods. Thus, it was higher in Rampur hybrid 4 (97,856 cobs ha$^{-1}$) in comparison to Rampur hybrid 6 (94,764 cobs ha$^{-1}$). Similarly, the number of cobs harvested from one hectare of land was higher in zero tillage (97,754 cobs ha$^{-1}$) in comparison to conventional tillage (94,867 cobs ha$^{-1}$). The number of cobs harvested per hectare was influenced significantly due to variation in plant population. It was significantly higher in 101 (1,08,898 cobs ha$^{-1}$) than in 55 (85,886 cobs ha$^{-1}$), 69 (93,482 cobs ha$^{-1}$) and 85 (96,976 cobs ha$^{-1}$) thousand plants ha$^{-1}$. Only the difference in number of cobs harvested ha$^{-1}$ between 69 and 85 thousand plants ha$^{-1}$ was non-significant. At low densities, many modern maize hybrids don't tiller effectively and quite often produce only one ear per plant (Sangoi, 2001). Malaviarachchi et al. (2007) also reported that average number of cobs per plant was not significantly different at each density level in maha 2004/05 whereas in yala 2005 season, which was accordance to our findings.

**Number of grains per cob**

The data shows that the number of grain rows per cob was higher in Rampur hybrid 6 (13.25) than in Rampur hybrid 4 (12.50) but the difference was not significant. Sampath et al. (2014) also reported non-significant number of grain rows per cob on different maize hybrid. On the other hand, the number of grains row per cob was not significantly affected by tillage methods. It was significantly higher in zero tillage (13.09) as compared to conventional tillage (12.66). Khan and Pervez (2011) observed significant relation between conventional and zero tillage system in respect of number of grain rows per cob in spring planted maize in Chitwan, Nepal. Further, it was also not affected significantly due to increase in plant population from 55 to 101 thousand plants ha$^{-1}$. However, it was higher in the treatment with 55 thousand plants ha$^{-1}$ (13.06) in comparison to 69 (12.76), 85 (12.73) and 101 (12.95) thousand plants ha$^{-1}$.

**Number of grains per row**

Number of grains per row produced by Rampur hybrid 4 (23.57) was found a little higher than that of Rampur hybrid 6 (23.29) but the difference was not significant. Similar trend was observed in tillage methods. The number of grains per row produced in zero tillage (23.74) was remarkably higher as compared to conventional tillage (23.11). Further, variation in plant
population did not show significant effect on grains per row of maize hybrids. However, it was higher in the treatment with 85 thousand plants ha\(^{-1}\) (24.11) than 55 (23.21), 69 (23.74) and 101 (22.66) thousand plants ha\(^{-1}\). Hashemi et al. (2005) reported a linear decline in number of grain rows/ear with increasing plant density. At high plant density the lowest number of grain/ear may be due to high competition for the resources such as light, moisture and fertilizer.

### Number of grains per cob

The number of grains per cob was found non-significantly higher in Rampur hybrid 6 (308.9) as compared to Rampur hybrid 4 (294.9). Dawadi and Sah (2012) reported non-significant difference number of kernel row per ear due to hybrid varieties, which is lined with our findings. In the same way, the number of grains per cob obtained in zero tillage (310.9) was remarkably higher than that of conventional tillage (292.8) but not significantly different. Further, non-significantly higher number of grains per cob was obtained with 85 (307.2) than 55 (302.9), 69 (303.9) and 101 (293.6) thousand plants ha\(^{-1}\). Malaviarachch et al. (2007) reported non-significant number of grain per cob due to planting density, which was accordance to our result.

### Weight of cob with grains

The weight of cob with grains did not differ significantly with the hybrid varieties of maize. However, it was slightly higher in Rampur hybrid 6 (95.6 g) than Rampur hybrid 4 (91.4 g). Mukhtar et al. (2011) also reported non-significant cob weight by hybrid varieties. Weight of cob with grain was not influenced significantly by tillage methods. However, it was remarkably higher in zero tillage (95.1 g) in comparison to conventional tillage (91.9 g). Sharma 2015 reported non-significant different between weight of cob by tillage and hybrid varieties. Similarly, non-significantly higher weight of cob with grain was observed in 85 (99.8 g) than 55 (94.6 g), 69 (94.9 g) and 101 (84.7 g) thousand plants ha\(^{-1}\).

### Weight of grains per cob

The weight of grains per cob was remarkably higher in Rampur hybrid 6 (76.6 g) in comparison to Rampur hybrid 4 (71.8 g) but not significantly different. Sharma (2015) also observed insignificant difference in respect of weight of grains per cob of hybrids RML 32/RML 17 (59.49 g) and Rampur hybrid 2 (61.59 g) in the summer planted maize in Chitwan, which is accordance to our result. Similarly, non-significant difference in grain weight per cob was obtained in tillage methods where its value was higher in zero tillage (76.6 g) as compared to conventional tillage (71.8 g). Srivastav (2013) also found non-significant difference between zero tillage (133.4 g) and conventional (126.4 g) in respect of weight of grains per cob in spring season in Chitwan, which was accordance to our findings. Similar to the

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### Table 3. Yield attributes of maize hybrids as influenced by tillage methods and plant population during winter season at NMRP, Rampur, Chitwan, Nepal, 2015/16

| Treatments | No of cobs per Hectare (,000/ha) | No of grains rows per cob | No of grains per row | No of grains per cob | weight of cob with grains (g) | Weight of grains per cob (g) | Thousand kernel weight (g) | GY t ha\(^{-1}\) | Shelling Percent (%) |
|------------|---------------------------------|---------------------------|---------------------|---------------------|-------------------------------|----------------------------|---------------------------|-----------------|-------------------|
| Varieties  |                                 |                           |                     |                     |                               |                           |                           |                 |                   |
| Rampur     | 97856                           | 12.50                     | 23.57               | 294.9               | 91.4                          | 71.8                       | 241.6                     | 5.88            | 78.39b            |
| hybrid 4   | 94764                           | 13.25                     | 23.29               | 308.9               | 95.6                          | 76.6                       | 247.7                     | 6.11            | 80.19a            |
| hybrid 6   | LSD (=0.05)                     | ns                        | ns                  | ns                  | ns                            | ns                         | ns                        | ns              | ns                |
|            | SEm (±)                         | 1527.4                    | 0.14                | 0.42                | 9.28                          | 1.70                       | 1.55                      | 4.91            | 0.19              |
| Tillage methods |                                |                           |                     |                     |                               |                           |                           |                 |                   |
| ZT         | 97754                           | 13.09a                    | 23.74               | 310.9               | 95.1                          | 76.6                       | 245.7                     | 6.25            | 80.58a            |
| CT         | 94867                           | 12.66b                    | 23.11               | 292.8               | 91.9                          | 71.8                       | 243.6                     | 5.74            | 78.0b             |
| LSD (=0.05) | ns                             | ns                        | ns                  | ns                  | ns                            | ns                         | ns                        | ns              | 2.39              |
| SEm (±)    | 780.9                           | 0.03                      | 0.44                | 5.88                | 3.57                          | 2.72                       | 4.2                      | 0.33            | 0.39              |
| Plant population (ha\(^{-1}\)) | 53.535                        | 85886a                    | 13.06               | 23.21               | 302.9                         | 94.6                       | 73.6                      | 242.5b          | 5.31c             |
|            | 69.444                          | 93482b                    | 12.76               | 23.74               | 303.9                         | 94.9                       | 74.5                      | 244.8ab          | 5.92b            |
|            | 85.470                          | 96976b                    | 12.73               | 24.11               | 307.2                         | 99.8                       | 80.4                      | 259.7ab          | 6.54a            |
|            | 1.01.010                        | 108898b                   | 12.95               | 22.66               | 293.6                         | 84.7                       | 68.2                      | 231.6b           | 6.21ab           |
| SEm (±)    | 6594                           | 0.14                      | 0.559               | 8.14                | 3.94                          | 3.20                       | 5.43                      | 0.20            | 0.25              |
| CV, %      | 8.1                             | 3.9                       | 8.3                 | 9.3                 | 14.6                          | 14.9                       | 7.7                       | 11.6            | 1.1               |
| Grand mean | 96310                          | 12.87                     | 23.43               | 301.9               | 93.5                          | 74.2                       | 244.6                     | 6.0             | 79.29             |

Means followed by the common letter(s) within each column are not significantly different at 5 % level of significance by DMRT; ns= non-significant, ZT= zero tillage and CT= convention tillage.
above results weight of grains per cob was statistically similar in respect of plant population. The value (80.4 g) of weight of grains per cob recorded in the treatment with 85 thousand plants ha$^{-1}$ was higher but similar to 55 (73.6 g), 69 (74.5 g) and 101 (68.2 g) thousand plants ha$^{-1}$ which also did not differ significantly.

Thousand kernel weight (g)

The thousand kernel weight was not influenced significantly by hybrid varieties and tillage methods. Hoshang (2012) reported non-significant difference in thousand grain weight with the change in plant population. It was remarkably higher in Rampur hybrid 6 (247.7 g) than in Rampur hybrid 4 (241.6 g). Dawadi and Sah (2012) and Malaviarachchi et al. (2007) reported same. Similarly in zero tillage produce more thousand grain weight (245.7 g) as compared to conventional tillage (243.6 g). Khan and Parvej (2010) mentioned that significantly higher thousand grain weight (335.75 g) was recorded in zero tillage than conventional tillage (219.82 g) in November planted maize in Bangladesh.

On the other hand, thousand grain weight was influenced significantly by plant populations. It was significantly greater in 85 (259.7 g) in comparison to 55 (242.5 g) and 101 (231.6 g) but remained at par with 69 (244.8 g) thousand plants ha$^{-1}$. Moreover, all these (55, 69 and 101) levels of plant populations were found similar to each other with respect of thousand grain weight. Contradict result was purposed by Malaviarachchi et al. (2007) and Dawadi and Sah (2012) who reported no variation in 100 seed weight under varying planting density.

Shelling percentage

The hybrid varieties used in the experiment differed significantly with respect to shelling percent. Significantly higher shelling percent was produced by Rampur hybrid 6 (80.19 %) as compared to Rampur hybrid 4 (78.39 %). Dawadi and Sah (2012) also reported maize hybrid (Gaurav and Rajkumar) also significantly different with respect to shelling percentage. Similarly, shelling percent was also affected significantly by tillage methods. Zero tillage gave significantly higher shelling percent (80.58 %) in comparison to conventional tillage (78.0 %). In contrast Srivastav (2013) found non-significantly higher shelling percent in conventional tillage (83.74 %) than zero tillage (83.07 %) in spring planted maize in Rampur, Chitwan. Moreover, shelling percent was also influenced significantly by plant population. It was significantly higher in 85 (80.6 %) as compared to 55 (77.79 %) and 69 (78.4 %) but was at par with 101 (80.37 %) thousand plants ha$^{-1}$. Beside it, the shelling percentages produced in population of 55 and 69 thousand plants ha$^{-1}$ were also similar to each other.

Grain Yield

Thus, the average grain yield of hybrid maize recorded in the experiment was 6.0 t ha$^{-1}$ and ranged from 3.19 to 7.76 t ha$^{-1}$ depending upon the varieties, tillage practices and plant densities, shown in table 3. In this experiment, the Rampur hybrid 6 produced higher grain yield (6.11 t ha$^{-1}$) as compared to Rampur hybrid 4 (5.88 t ha$^{-1}$) but the differences was not significant. Wajid et al. (2007) and Malaviarachchi et al. (2007) also reported non-significant difference in grain yields of hybrids, which was lined with our findings. The results of this experiment showed that the tillage methods did not affect significantly on grain yields of hybrid maize. However, zero tillage gave higher grain yield (6.25 t ha$^{-1}$) in comparison to conventional tillage (5.74 t ha$^{-1}$). Moreover, Pandey and Chaudhary (2014) reported that grain yields were not affected significantly by tillage methods (7.53 and 7.37 t ha$^{-1}$ in conventional and zero tillage, respectively) in Chitwan, Nepal. Similar results were obtained by Srivastav (2013) in Chitwan, Nepal. Besides this, the plant density showed significant effect on grain yield formation of maize hybrids. Dawadi and Sah (2012) and Mohseni et al. (2013) were mentioned that the grain yield of the hybrid maize differed significantly with the change in plant densities. Hence, significantly higher grain yield (6.54 t ha$^{-1}$) was obtained from the population of 85.470 plants ha$^{-1}$ than 55.555 (5.31 t ha$^{-1}$) and 69.444 (5.92 t ha$^{-1}$), but remained at par with 1.01.010 plants ha$^{-1}$ (6.21 t ha$^{-1}$) which was similar to 69.444 plants ha$^{-1}$ but significantly superior over 55.555 plants ha$^{-1}$ in respect of grain yield production. Finally, the difference in grain yields obtained from 55 and 69 thousand plants ha$^{-1}$ was also significant. Zeleke et al. (2017) reported significantly different grain yield by planting density which was lined with our result..Sorkhi and Fateh (2014) mentioned that the grain yield of the maize hybrids (SC 301 and SC 320) increased significantly with the increase in plant density from 60 to 80 and then declined non significantly at 90 thousands plants ha$^{-1}$ in an experiment, which was accordance to our result.

CONCLUSIONS

The phenological stages including germination and physiological maturity were not significantly influenced by maize hybrids. However, the tassel, silk, and milking stages were significantly delayed in Rampur hybrid 6 than Rampur hybrid 4. On the other hand, all phenological stages were not significantly affected by tillage methods. However, it was remarkably delayed in zero tillage than conventional tillage. Thus, the maize hybrids took longer duration...
(166.08 DAS) in zero tillage than in conventional (165.92 DAS) to attain physiological maturity stage. Similarly, most of the phenological stages including knee high and physiological maturity differed non-significantly due to change in plant population from 55 to 101 thousand plants ha⁻¹. Both maize hybrids (Rampur hybrid 4 and Rampur hybrid 6) produced similar grain yield (5.88 and 6.11 t ha⁻¹, respectively). Similarly, both tillage methods i.e. zero and conventional tillage also produced similar grain yield (6.25 t ha⁻¹ and 5.74 t ha⁻¹, respectively). Beside this, the plant population showed significant effect on grain yield of maize hybrids.

ACKNOWLEDGMENTS

Authors were grateful to NMRP, Rampur for providing the research material

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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