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Research Article

TILLAGE, RESIDUE, FERTILIZER AND WEED MANAGEMENT ON PHENOLOGY AND YIELD OF SPRING MAIZE IN TERAI, NEPAL

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Abstract

With the aim of developing crop management technologies that reduce the yield gap of maize (*Zea mays* L.) in Nepal, a study was carried-out to determine whether the grain yield of maize could be manipulated through tillage, residue, and nutrient and weed management practices. The effect of tillage (conventional and no tillage), residue (residue retained and residue removed), fertilizer (recommended doses of fertilizer and farmers' doses of fertilizer) and weed management practices (herbicide use and manual weeding) on phenology and grain yield of maize were investigated under maize-rice cropping system in Rampur, Nepal during 2013. The experimental results revealed that no tillage had significant effect on grain yield (6.64 Mg ha-1) and phenological parameters like days to silking, physiological maturity and seed fill duration. Similarly, residue retained treatment had significant effect on grain yield (7.02 Mg ha-1) and phenological parameters. Research dose of fertilizer had significant effect on phenological parameters and grain yield (8.42 Mg ha-1). However, weed management factor did not influence significantly on grain yield and phenological parameters. The grain yield increased in no tillage by 23.19% over conventional tillage, residue retained by 39.84% over residue removed, recommended doses of fertilizer by 132.60% over farmer dose of fertilizer. Thus, no tillage, residue retention, recommended doses of fertilizer and use of herbicide for weed management can be alternative technologies for sustainable higher grain yield.

Key words: Maize; tillage; residue; fertilizer; yield; phenology

Introduction

Maize is the second most important cereal crop in Nepal after rice, in area, production and productivity (2.35 ton ha^{-1}) (MoAD, 2014). The yield potential of four hybrid maize in Chitwan, Terai (with GDD 1500 to 1800) was reported as 11.3-27.4 t ha^{-1} for extra short, 13.1-29.7 t ha^{-1} for short, 14.1- 31.3 t ha^{-1} for intermediate and 15.4-32.7 t ha^{-1} for long duration varieties (Timisinia *et al.*, 2010a) while the yield is much less (3.01 t ha^{-1}) than this yield potential (MoAD, 2014). To decrease this yield gap various crop management practices like no tillage, residue retention, fertilizer dose and weed management under conservation agriculture may have the vital role.

Conventional tillage has a long been contributing negatively to soil quality in fracturing the soil, disrupting the soil structuring, accelerating surface runoff and soil erosion. Intense tillage system reduced the soil organic carbon (SOC) content 20% less after 20 year (Mann, 1986) but adopting conservation tillage with crop rotation, soil organic carbon level was maintained or even increased due to least amount of soil disturbance (Varvel and Wilhem, 2010). Introduction of crop residue in the soil offers the best means to restore carbon in agriculture soils (Regmi *et al.*, 2002). High yielding crop like maize require large amount of mineral nutrients from soil which require proper nutrient management strategy that minimize loss and maximize the efficiency of use. Timsina *et al.* (2010b) hypothesized that the establishment of maize after rice with reduced or no tillage, and retaining of crop residues, could help to conserve soil organic matter (SOM) and maintain soil fertility if improved nutrient management is practiced. Similarly, weed infestation is one of the major causes that leads 20 to 80% maize reduction in yield (Chikoye and Ekeleme, 2003).

Conservation agriculture like zero tillage, residue management along with proper nutrient management strategy and effective weed management practice helps to conserve the soil properties, reduce the cost of production, reduce the yield losses due to weed infestation and produce the sustainable yield in longer run, which lead to the sustainability of rice-maize cropping system. Therefore, an attempt was made in order to evaluate the impact of tillage, residue, fertilizer and weed management on phenology, yield and yield contributing parameters of spring maize in Terai, Nepal

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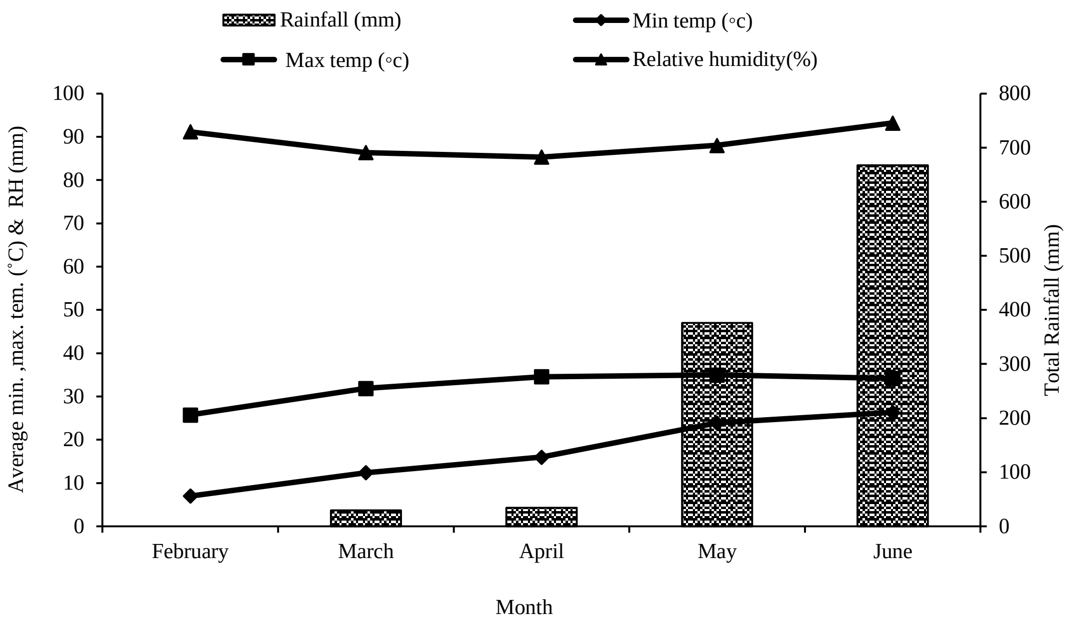


Fig. 1. Weather condition during the course of experimentation at Rampur, Chitwan, Nepal during February to June, 2013

Materials and Methods

The field experiment was conducted at the farm of National Maize Research Program (NMRP), Chitwan, Nepal from February to June 2013 during spring season. This location is situated at elevation of 256 masl in the inner Terai region. The experiment was conducted at the field where Maize-Rice cropping system was followed for fourth season. The research was conducted in strip-split plot design having four factors with two level of each. In strip, vertical factor with tillage method and horizontal factor with residue management; in split, main plot factor with fertilizer management and sub- plot factor with weed management practice was applied. Tillage factor consisted of i) conventional tillage and ii) no tillage; residue management with i) 35 cm rice residue retained and ii) residue removal; fertilizer management with i) farmer's practice level of fertilizer dose i.e. 10 ton ha^{-1} FYM +70:30:50 kg NPK ha^{-1} (Paudel and Matsuoka, 2008) and ii) Research-based recommendation dose i.e. 180:115:160 Kg NPK ha^{-1} under yield target of 8 t ha^{-1} for hybrid maize (ACIAR, 2009); and weed management with i) herbicide use i.e. Atrazine, pre-emergence only @ 1.5 kg a. i. ha^{-1} within 48 hours of seeding and ii) manual weeding i.e. hand pulling i.e. at the interval of one month as not to disturb the soil under no tillage. No tillage and residue retention was followed for fifth season with no tillage and alternate maize- rice residue retention on same plot. In research based fertilizer dose, 60:115:80 kg NPK ha^{-1} was applied at basal dose and remaining N at V_6 stage (60 kg N ha^{-1}) and V_{10} stage (60 kg N ha^{-1}) along with remaining K (80 kg K_2O ha^{-1}) at V_{10} stage of maize. While in the level of 10 t ha^{-1} FYM +70:30:50 kg NPK ha^{-1}, 10 t ha^{-1} + 24:30:25 kg NPK ha^{-1} was applied at basal dose and remaining N at V_6 stage (23 kg N ha^{-1}) and V_{10} stage (23 kg N ha^{-1}) along with remaining K (25 kg K_2O ha^{-1}) at V_{10} stage of maize. A hybrid maize (Rampur Hybrid-2) was planted within the single plot of 34.02 m^2 (5.4 m × 6.3 m) with spacing of 60 cm × 30 cm having nine rows. Data were recorded on phenological parameters like days to 90% tasseling, silking, physiological maturity; grain yield, ear length and number of kernel rows ear^{-1}. MSTAT-C package was used for data analysis and Duncan's Multiple Range Test (DMRT) was used for comparing the means.

Weather condition during experimentation

During the crop season, from February to June the mean maximum temperature ranged from 25.73 °C to 34.98 °C. Similarly, the mean minimum temperature ranged from 7.02 °C to 26.33 °C. About 1107.1 mm of total rainfall was received during the entire growing season for maize (Fig. 1).

Results and Discussion

Tasseling

Days to 90% tasseling was significantly influenced by residue and fertilizer management. Residue incorporated level and research dose of fertilizer had significantly earlier tasseling in comparison with residue removal and farmer dose of fertilizer respectively (Table 1). Gul *et al.* (2014) reported 50% tasseling was observed significantly earlier in the treatment with mulches. Dawadi and Sah (2012) reported earlier tasseling @ 200 kg ha^{-1} nitrogen as compared to 120 kg ha^{-1}. Amanullah *et al.* (2010) reported that, significantly earlier tasseling with 90 kg ha^{-1} of phosphorus as compared to 30 kg ha^{-1} and Asif *et al.* (2007) also reported significantly earlier tasseling with 90 kg ha^{-1} potassium application as compared with 30 and 60 kg ha^{-1}.

Silking

Days to 90% silking was also significantly influenced by tillage, residue and fertilizer whereas it was not significantly influenced by weed management factor. No tillage and residue retained significant level ($p \leq 0.05$) earlier silking in comparison to conventional tillage and residue removed level respectively. Similarly, research dose of fertilizer had significantly ($p \leq 0.01$) earlier days to silking in comparison with farmer dose of fertilizer respectively (Table 1). Khan and Parvej (2010) reported significantly earlier silking in quality protein maize (QPM) when rice straw was used as mulch and significantly earlier silking as the nitrogen rate increases from 120 and 160 to 200 kg ha^{-1} (Dawadi and Sah, 2012). Similarly, earlier silking was observed with high dose of phosphorus (Amanullah *et al.*, 2010) and potash (Asif *et al.*, 2007).

Physiological maturity

No tilled and residue retained level had significantly ($p \leq 0.05$) later physiological maturity in comparison to conventional tillage and residue removed respectively. Similarly, research dose of fertilizer had significantly ($p \leq 0.01$) later physiological maturity in comparison with farmer dose of fertilizer. But weed management factor did not influence significantly on the physiological maturity of maize (Table 1). Khan and Parvej (2010) reported significantly earlier days to maturity in tilled condition as compared with no tilled condition in QPM. BK *et al.* (2013) reported that the residue retained treatment had significantly longer days to maturity than residue removed treatment. This might be due to the moisture availability in no tillage and residue used level which caused longer time for physiological maturity. Residue retained for longer period, might have increased soil organic matter and more mineralized nutrient. Higher nitrogenous level delays the senescence of leaves and increases the succulence of plants, so that plants might have stayed green for long period of time. Dawadi and Sah (2012) also reported that days to physiological maturity was significantly longer with increasing level of nitrogen from 120,160 to 200 kg ha^{-1}. Asif *et al.* (2007) reported that there was significantly later physiological maturity at 60 kg ha^{-1} potassium as compared to 30 kg ha^{-1}.

Seed fill duration (SFD)

Seed fill duration was significantly influenced by residue and fertilizer dose. Residue retained level had significantly ($p \leq 0.05$) longer seed fill duration in comparison with residue removed. Research dose of fertilizer had significantly ($p \leq 0.01$) higher seed fill duration in comparison with farmer dose of fertilizer (Table 1). The moisture conservation in no tillage and high organic matter in residue retained treatment might have caused longer seed fill duration. Nitrogenous fertilizer increased the seed fill duration with increased level (Dawadi and Sah, 2012).

Ear length

Ear length was significantly influenced by tillage, residue and fertilizer management. No tillage had significantly ($p \leq 0.05$) longer ear length in comparison with conventional tillage. Similarly, residue retained level and research dose of fertilizer had significantly ($p \leq 0.01$) longer ear length in comparison with residue removed and farmer dose of fertilizer respectively. Ear length of QPM increased significantly in no tillage and residue retained in comparison with conventional tillage and residue removed (Khan and Parvej, 2010). Ear length of maize increased significantly with increasing nitrogen levels (Onasanya *et al.*, 2009) and phosphorus level (Amanullah *et al.*, 2010).

Table 1. Effect of tillage, residue, fertilizer and weed management on phenology of spring maize

Treatments	Phenology of maize (days)			
	90% Tasseling	90% Silking	Physiological maturity	SFD
Tillage methods				
CT	85.42	89.04^{a}	131.75^{b}	46.33
NT	83.92	86.75^{b}	134.04^{a}	50.13
LSD	NS	2.07*	2.07*	NS
SEm±	0.42	0.34	0.34	0.76
Residue management				
RK	83.29^{b}	86.13^{b}	134.67^{a}	51.38^{a}
RR	86.04^{a}	89.67^{a}	131.12^{b}	45.08^{b}
LSD	1.89*	2.37*	2.37*	3.93*
SEm±	0.31	0.39	0.39	0.65
Fertilizer doses				
FD	88.21^{a}	91.50^{a}	131.29^{b}	43.08^{b}
RD	81.13^{b}	84.29^{b}	134.50^{a}	53.38^{a}
LSD	2.02**	2.47**	2.47**	3.29**
SEm±	0.43	0.52	0.52	0.69
Weed management				
Herbicide	84.54	87.79	133.00	48.46
Manual	84.79	88.00	132.79	48.00
LSD	NS	NS	NS	NS
SEm±	0.36	0.43	0.43	0.50
CV%	2.08	2.41	1.60	5.02
Grand mean	84.67	87.90	132.90	48.23

*= significantly different at $p \leq 0.05$, **= significantly different at $p \leq 0.01$ by DMRT, LSD value differs according to the level of significance, CT= conventional tillage, NT= no tillage, RK= residue kept, RR= residue removed, FD= farmer dose, RD= Research dose, SFD= Seed fill duration

Number of kernel rows per ear

Number of kernel rows ear^{-1} was significantly influenced by residue and fertilizer management. Residue incorporated level had significantly ($p \leq 0.05$) higher number of kernel rows ear^{-1} in comparison with residue removed level. Similarly, research dose of fertilizer had significantly ($p \leq 0.01$) more kernel rows ear^{-1} in comparison with farmer dose of fertilizer. Kernel rows ear^{-1} significantly increased with the increased level of nitrogen (Dawadi and Sah, 2012).

Grain yield

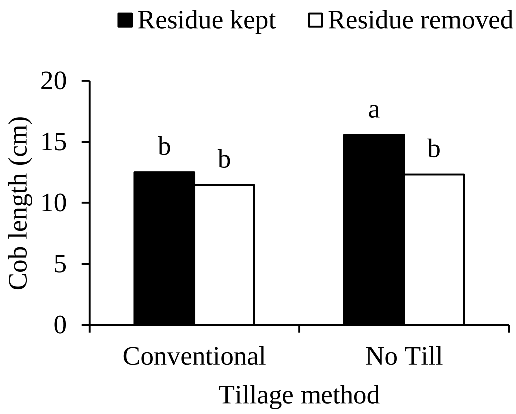
Grain yield of maize was significantly influenced by tillage, residue and fertilizer management. Grain yield was obtained significantly ($p \leq 0.05$) higher in no tillage (6.64 t ha^{-1}) and residue incorporated level (7.02 t ha^{-1}) in comparison with conventional tillage (5.39 t ha^{-1}) and residue removed level (5.02 t ha^{-1}) respectively. Research dose of fertilizer obtained significantly ($p \leq 0.01$) higher grain yield (8.42 t ha^{-1}) than farmer dose of fertilizer (3.62 t ha^{-1}) but in case of weed management factor grain yield was not significantly influenced (Table 2)

There was stable yield increase in no tillage and residue incorporated level in comparison with conventional tillage and residue removed level respectively in long term basis of conservation agriculture (Govaerts *et al.*, 2006). Seed yield of hybrid maize increased significantly with the increase of nitrogen level up to 300 kg ha^{-1}, but decreased the yield when nitrogen level was increased up to 450 kg ha^{-1} (Karasu, 2012). Longer seed fill duration in no tillage, residue retained and high dose of fertilizer might have contributed to sufficient time and assimilated food material to increase the grain weight and total grain number of maize. Adequate nitrogen supply from source to sink might have caused the large sized ears having heavier and bold grains contributing to weight.

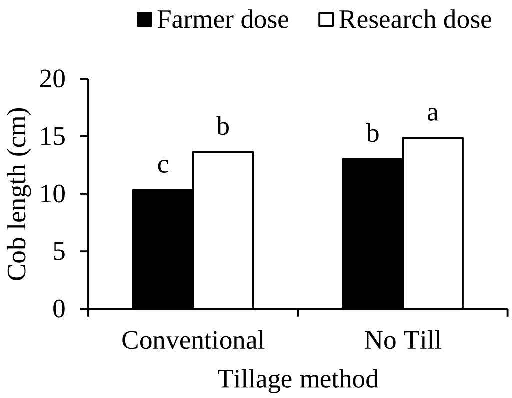
Table 2. Effects of tillage, residue, fertilizer and weed management on ear length, number of kernel rows ear^{-1} and grain yield of spring maize

Treatments	Yield attributes and grain yield		
	Ear length (cm)	Number of kernel rows ear^{-1}	Grain yield (t ha^{-1})
Tillage methods			
CT	11.98^{b}	14.59	5.39^{b}
NT	13.94^{a}	14.70	6.64^{a}
LSD	1.69*	NS	1.01*
SEm±	0.28	0.23	0.17
Residue retention			
RK	14.03^{a}	14.87^{a}	7.02^{a}
RR	11.89^{b}	14.42^{b}	5.02^{b}
LSD	0.68**	0.32*	1.13*
SEm±	0.05	0.05	0.19
Fertilizer doses			
FD	11.68^{b}	14.23^{b}	3.62^{b}
RD	14.24^{a}	15.07^{a}	8.42^{a}
LSD	0.60**	0.74**	0.45**
SEm±	0.13	0.16	0.09
Weed management			
Herbicide	12.86	14.69	6.07
Manual	13.06	14.60	5.97
LSD	NS	NS	NS
SEm±	0.14	0.15	0.18
CV%	5.30	5.15	14.28
Grand mean	12.96	14.65	6.02

*= significantly different at $p \leq 0.05$, **= significantly different at $p \leq 0.01$ by DMRT, LSD value differs according to the level of significance, CT= conventional tillage, NT= no tillage, RK= residue kept, RR= residue removed, FD= farmer dose, RD= Research dose



2a

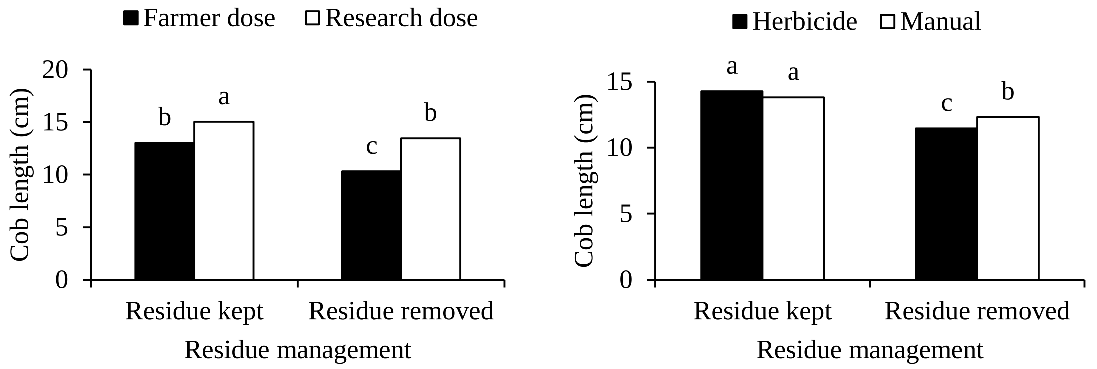


2b

Fig. 2: Interaction effect on cob length between (a) tillage and residue ($p \leq 0.05$) (b) tillage and fertilizer ($p \leq 0.01$)

Interaction effect on ear length

The interaction between tillage and residue showed significantly ($p \leq 0.05$) longer ear length at no tillage and residue incorporated level. In interaction between tillage and fertilizer, there was significantly ($p \leq 0.01$) longer ear length at no tillage and research dose of fertilizer. The interaction between residue and fertilizer showed significantly ($p \leq 0.05$) higher ear length at residue incorporated with research dose of fertilizer. Similarly, in interaction between residue and weed management factor, significantly ($p \leq 0.01$) higher ear length was obtained when residue was incorporated either with herbicide use or manual weeding (Fig. 2 and 3). Sharafi *et al.* (2013), reported that longest ear length was obtained at the interaction between no tillage or conventional tillage with residue incorporated of wheat with high dose of nitrogen (i.e. 102.5 and 138 kg ha^{-1}).



3a 3b

Fig. 3. Interaction effect on ear length between (a) residue and fertilizer ($p \leq 0.05$) (b) residue and weed management *($p \leq 0.01$)*

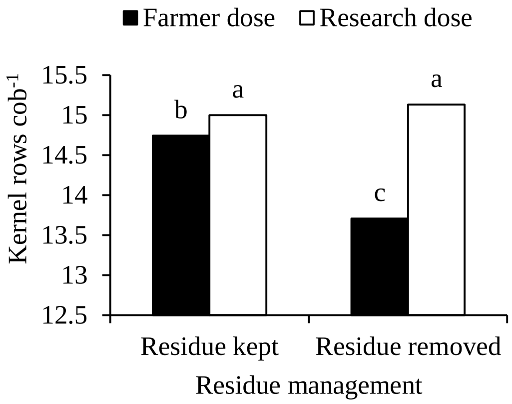
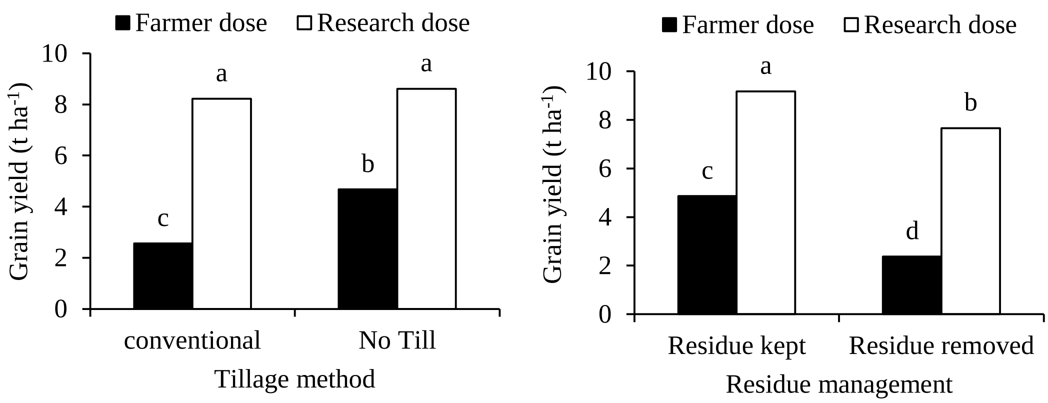


Fig. 4: Interaction effect between residue and fertilizer on kernel rows per cob ($p \leq 0.05$)



5a *5b*

Fig. 5: Interaction effect on grain yield between (a) tillage and fertilizer ($p \leq 0.01$) (b) residue and fertilizer ($p \leq 0.01$)

Interaction effect on kernel rows ear^{-1}

In kernel rows ear^{-1}, interaction effect was observed only between residue and fertilizer management. Research dose of fertilizer either with or without residue showed significantly ($p \leq 0.05$) more kernel rows ear^{-1} as compared to other level of interaction (Fig. 4).

Interaction effect on maize grain yield

The interaction effect of different factors on maize grain yield was observed only between tillage and fertilizer, residue and fertilizer and between residue and weed management. In case of interaction between tillage and fertilizer management, the effect of research dose of fertilizer either with conventional or no tillage had significantly ($p \leq 0.01$) higher grain yield over other levels (Fig. 5a). Similarly, the interaction between residue and fertilizer management showed significantly ($p \leq 0.01$) higher grain yield in research dose of fertilizer with residue incorporated than other three level of interaction (Fig. 5b). But in case of interaction between residue and weed management factor residue incorporated with herbicide used level showed significantly ($p \leq 0.05$) higher grain yield than other three level of interaction (Fig. 6).

The interaction effect between tillage and fertilizer, fertilizer and residue management was observed in maize grain yield as similar to Karasu (2012), where significantly higher grain yield was observed with interaction between residue retained either with no tillage or conventional tillage with high nitrogen dose i.e.103.5 and 138 kg ha^{-1}. The interaction between tillage and nutrient might have occurred due to the sufficient amount of nutrient in high dose of fertilizer and efficient use of nutrient in no tillage due to the moisture availability. The interaction between residue and nutrient might have observed due to sufficient use of mineralized nutrient in residue incorporated treatment and efficient use of high dose of fertilizer. Interaction between residue and weed management might have observed due to the effectiveness of residue to retard the growth of weeds and herbicide might have effect from initial growth of weeds.

Correlation coefficient among phenological parameters, ear length, number of kernel rows ear^{-1} and grain yield is shown in Table-3.

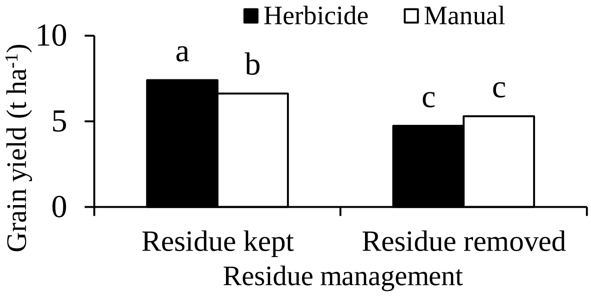
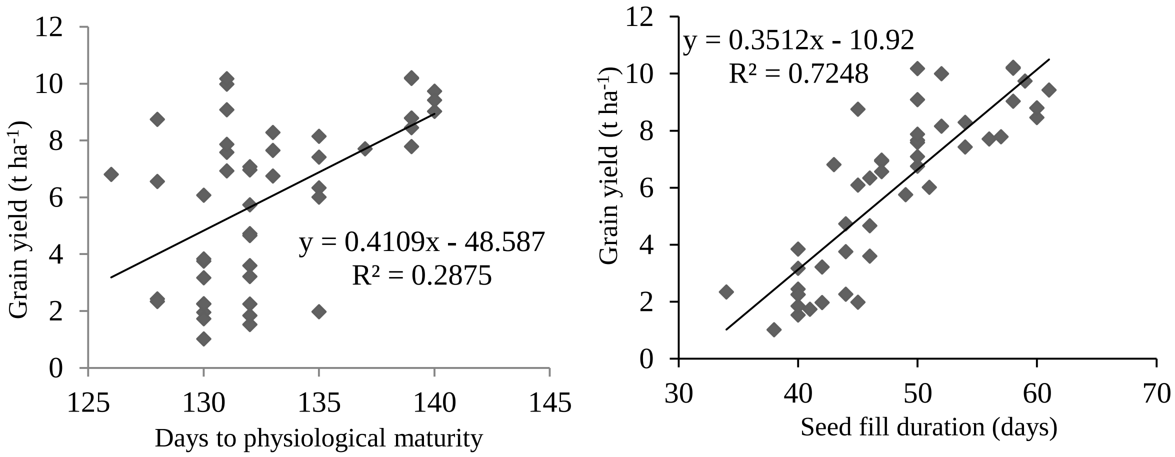


Figure 6. Interaction effect on grain yield between residue and weed management ($p \leq 0.05$)



7a 7b

Fig. 7: Relationship between grain yield of maize and (a) days to physiological maturity (b) seed fill duration (days)

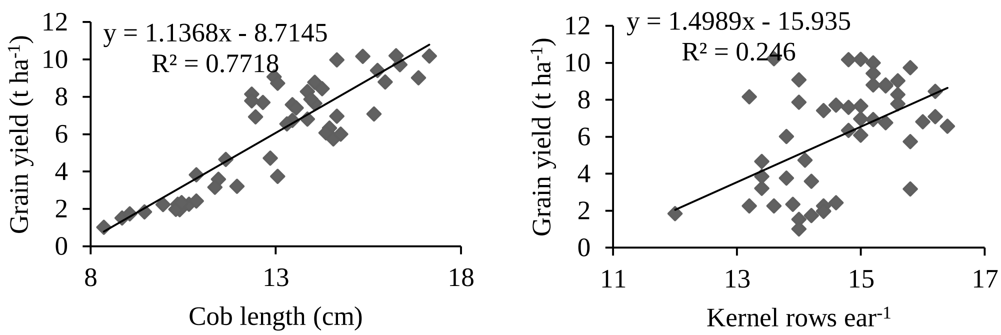


Fig. 8: Relationship between grain yield and (a) ear length (cm) (b) number of kernel row ear^{-1}

Table 3: Correlation coefficient among phenological parameters, ear length, number of kernel rows ear^{-1} and grain yield

	Silking	P. maturity	SFD	Ear length	N. row	Grain yield
Tasseling	.931**	-.479**	-.881**	-.793**	-.578**	-.903**
Silking		-.466**	-.831**	-.804**	-.540**	-.879**
P. maturity			.837**	.540**	.174	.536**
SFD				.785**	.454**	.851**
Ear length					.536**	.879**
N. row						.496**

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)
SFD= Seed fill duration, P. maturity= Physiological maturity, N. row= number of kernel rows ear^{-1}

Conclusion

Combination of no tillage (seeding with jab planter in no tilled field), residue retention (35m anchored rice residue), recommended doses of fertilizer (180:115:160 Kg NPK ha^{-1} under yield target of 8 t ha^{-1} for hybrid maize) and application of herbicide (Atrazine as a pre-emergence herbicide @1.5 kg a.i ha^{-1}) within 48 hours of maize seeding for weed management is recommended for the spring maize hybrid growing farmers in the Terai region of Nepal.

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