INTERVENTION OF CLIMATE SMART AGRICULTURE PRACTICES IN FARMERS FIELD TO INCREASE PRODUCTION AND PRODUCTIVITY OF WINTER MAIZE IN TERAI REGION OF NEPAL

J.J. Gairhe[1*] and M. Adhikari[2]
[1]Paklihawa Campus, Institute of Agriculture and Animal Science, Nepal
[2]Mississppii State University, USA
*janma@iaas.edu.np

ABSTRACT

Climate change has been the burning issue in agriculture sector. The research world is focused on developing appropriate technology, innovations and concept to cope up this change. The Climate Smart Agriculture [CSA] has been adapted globally for cultivation and crop management in changing context without compromising yield and productivity. The CSA involves wide range altered techniques and innovations like using resilient varieties, water management, zero tillage, legumes incorporation, cover cropping, site specific fertilizer management, variation in planting date etc. Grounding on the similar practices and principles of CSA, the research in maize was conducted in 2014 in farmers' field of Eastern Nepal. Three progressive farmers with 1 hector of land were selected and Maize was cultivated using Zero tillage seed cum fertilizer driller tractor. This field experiment considers farmers as replication with six different treatments. All treatments differ to each other based on nutrient management, water management, residue management, tillage practice, crop establishment, and inclusion of legumes in the cropping system. Six treatments are codded as follows: Current Irrigated (CI), Improved Irrigated Low (IIL), Improved Irrigated High (IIH), Climate Smart Agriculture-Low (CSA-L), Climate Smart Agriculture-Medium (CSA-M), and Climate Smart Agriculture-High (CSA-H). Significant impact of intervention was observed in yield and yield attributes in the trial with climate smart agriculture practices than in conventional practices of farmers. Plant density, ear number, filled grains per cob and grain yield was substantially higher in climate smart practices revealing CSA to be the appropriate technology to minimize potential loss of climate change.

Key Words: Climate change, Climate Smart Agriculture.

INTRODUCTION

Maize (*Zea mays* L.) is the second most staple food crops of Nepal, while it is the most important and primary cereal crop in the hills of Nepal, where the grain is used for human consumption and the Stover for animal fodder. It is usually used for food, feed, fodder, and fuel and is a significant source of energy (Adhikari, 2008). Maize cultivation is a way of life for most farmers in the hills of Nepal. It is grown under rainfed conditions during the summer (April- August) as a single crop or relayed with millet later in the season. More than two thirds of the maize produced in the mid hills and high hills is used for direct human consumption at the farm level and the ratio of human consumption to total.

Of the total maize area about 78% falls in the hills Area (mid Hills 70%, and high hills 8%). Maize is generally grown under rain- fed condition in Nepal with basal application of low quantity of Farm yard manure. Unavailability of quality seed of farmer's preferred varieties at right time, in desired quantities and at reasonable price is the major constraint for increasing production (Adhikari *et al.,* 2003). Most of the farmer keep their own seeds year after year. More than 88% farmers used farm saved seeds (Gurung, 2011). Maize yields fluctuate seasonally and annually especially in the hills. Although maize yields increased slightly over the past five years, there has been very little yield improvement when compared to nationwide yield 30 years ago. This is probably due to the expansion of maize cultivation into less suitable terrain, declining soil fertility, and the adoption of improved management practices. While productivity in the country is almost stagnant, the overall demand for maize driven by increased demand for human consumption and livestock feed is expected to grow by 4% to 6 % per year over the next 20 years. Thus, Nepal will have to resort to maize imports in the future if productivity is not increased substantially. National average yield of maize is 2.5 t/ha. Seed replacement rate in Maize is about 11.3% (Pokharel, 2013). The yield gaps in major crop were measured based on existing yield and maximum yield observed for the crop by the Nepal Agriculture Research Council and Department of Agricultural Development of Nepal. The crop yield is a difference between maximum yield and existing yield for each crop. Large yield gaps exist in all major crops (paddy, wheat, maize and millet) in Nepal.

Considering the potential impacts of climate change on agriculture in South Asia, it is essential to promote climate smart practices and technologies to address the challenges imposed by climate change. Climate change is further compounding the agricultural problems and it is likely to continue in future. Increased temperature, erratic rainfall pattern, extreme events, dry spell and rapid snow melting are affecting water availability and soil moisture. Some of these events are also contributing to spread of new insect and disease pests, loss of crops by floods and droughts, change in physiology, eventually leading to poor crop production and food insecurity (Chaudhary and Bawa, 2011). It is thus vital to increase crop production and improve farmers' ability to cope with climate change problems, leading to more resilient social and ecological systems and healthy and peaceful society. In another word, agriculture needs to be made responsive to unpredictable and uncertain climate vagaries, so that good crops harvest and food can be secured. Climate Smart Agriculture (CSA) has been therefore emerged as an approach to improve resilience (adaptation), reducing emission of greenhouse gases (mitigation) and enhancing food security (livelihoods) (FAO 2013). As a result, a number of methods and practices are proposed to address the challenges in agriculture. These includes: i) improvement/change in agronomic practices, ii) introduction of climate-smart technologies, and iii) provision of climate services and agro-advisories. Potential of such practices in minimizing climatic risks in agriculture have been widely discussed (Vermeulen *et al.,* 2012; Howden *et al.,* 2007). Many of these interventions have been successful in raising the production, income and building resilience of farming communities in many locations in South Asia (Khatri-Chhetri *et al.,* 2016; Aryal *et al.,* 2015; Jat *et al.,* 2014; Sapkota *et al.,* 2015). However, evidences of climate smart agricultural practices and technologies in reducing climate change impacts and improving crop yields are rarely available. Thus, evaluation of climate smart package of practices (PoP) that can promote resilience, increase crop yield, and reduce GHG emissions from the crop field is essential. This evaluation can help to generate evidences for developing a business model and prioritizing investment in climate smart practices and technologies in cereal crops.

The goal of this research project is in line with the CCAFS programme objectives and aims to assess adaptation potential of agriculture in Nepal under a changing climate and explore new ways of helping vulnerable rural communities adjust to these changes. The project involves pilot testing and evaluation of climate smart practices and technologies in agriculture sector and providing policy inputs to the Government of Nepal.

MATERIALS AND METHODS

Treatments and experimental design

The research was carried out in farmers' field in Birgunj of Central Nepal. Four progressive farmers of Prastoka VDC having 1/2 hector of land were selected and maize was cultivated using Zero tillage seed cum fertilizer driller tractor.

Table 1: Treatments for Climate Smart Agriculture in Maize

Interventions	T1	T2	T3	T4	T5	T6
Planting	Farmer's practice	Farmer's practice	Drilling	Drilling	Drilling	Drilling
Cultivars	Common variety: Rampur Composite	Common variety: Rampur Composite	Common variety: Rampur Composite	Improved Variety: Pioneer 3522	Improved Variety: Pioneer 3522	Improved Variety: Pioneer 3522
Fertilizer	FFP (rate and method)	FFP (Rate and method)	FFP (Rate and method)	Recommended dose of NPK	LCC based	SSNM-sensor based
Water Management	Farmer's current practice	Farmer's current practice	4 Irrigations, Method- flood, Efficiency 0.40	4 Irrigations, Method- fixed amount automatic, Efficiency 0.70	Need based using Tensiometer	Need based using Tensiometer
Laser Levelling	None	None	None	Yes, Efficiency .70	Yes, Efficiency .70	Yes, Efficiency .70
Residue Management	Farmer's current practice	Incorporate rice straw (50% of harvested amount)	Incorporate rice straw (50% of harvested amount)	Incorporate rice straw (50% of harvested amount)	Incorporate rice straw (50% of harvested amount)	Incorporate rice straw (50% of harvested amount)
Tillage	Farmer's current practice	Farmer's current practice	1 Drill no till (Zero Tillage)	1 Drill no till (Zero Tillage)	1 Drill no till (Zero Tillage)	1 Drill no till (Zero Tillage)
Legume inclusion	None	None	Yes	None	None	Yes

Note: FFP: Farmers Fertilizer Practice, LCC= Leaf Color Chart, SSNM= Site Specific Nutrient Management

This field experiment considered farmers as replication with six different treatments. Rice was the preceding crops of the research plot and stubbles residues were deliberately left so as to maintain higher organic matter in climate smart practices while, no stubbles were retained in treatments of conventional farmers practice. All treatments differed to each other based on nutrient management, water management, residue management, tillage practice, crop establishment, and inclusion of legumes in the cropping system (Table 1). Six treatments are coded as follows: Current Irrigated (CI) as T1, Improved Irrigated Low (IIL) as T2, Improved Irrigated High (IIH) as T3, Climate Smart Agriculture-Low (CSA-L) as T4, Climate Smart Agriculture-Medium (CSA-M) as as T5, and Climate Smart Agriculture-High (CSA-H) as T6. Other things remaining constant, there was distinct variation among CSA L, CSA- M and CSA – H in terms of fertilizer application and irrigation schedule.

Recommended dose of fertilizer 120:60:40 kg NPK is applied in CSA L, while Leaf color chart and site-specific nutrient management methods are practiced under CSA - L and CSA – L respectively (Table -1). Moreover, conventional high frequency irrigation schedule (4 irrigations) were applied for climate smart agriculture low while precise moisture management based on tensiometer readings was followed under CSA – M and CSA – H. Proper agronomic and management practices like weeding, hoeing, manuring and control measures against pest and pathogens were followed throughout the research period so as to minimize error and deviation from external factors. Various biometrical and yield attributing traits were recorded, and data were entered in MS excel. The data was subjected to Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) using R 3.3.0 statistical package.

RESULTS AND DISCUSSION

Table-2 Yield and yield attributes under variable climate smart agriculture practices

Treatment	Plant Population	Ear No Per Hector	Grain Per Row	TGW	Grain Yield (Ton/ha)	Biomass (ton/ha)
Farmers Practice	36458 ^{c}	38541^{c}	34.80 ^{c}	284.3^{b}	4.07 ^{c}	21.85 ^{c}
Improved Irrigated Low	45486 ^{b}	46180 ^{bc}	36.90 ^{ab}	304 ^{ab}	4.49^{bc}	23.21 ^{bc}
Improved Irrigated High	52430^{ab}	53125 ^{ab}	35.60^{bc}	318^{a}	4.62 ^{bc}	23.90^{bc}
Climate Smart Agriculture Low	53819 ^{ab}	51041^{ab}	35.55^{bc}	310.1^{a}	4.49 ^{bc}	24.34^{bc}
Climate Smart Agriculture Medium	55555 ^{a}	54861 ^{a}	37.75 ^{b}	317.3^{a}	4.74^{b}	26.49^{b}
Climate Smart Agriculture High	53819 ^{ab}	54166^{ab}	38.8 ^{a}	323.2^{a}	5.45 ^{a}	32.46 ^{a}
Significance	***	***	**	**	***	***
Grand Mean	49594	49652.78	36.15	309.65	4.64	25.38
LSD	9005	7844.096	2.76	22.78	0.59	3.67
EMS	37501903	28454463	3.54	240	0.16	6.26
CV	12.34	10.74	5.2	5	8.68	9.85

Plant density and ear number per hector

The variation in plant population and ear number was found to be significant among different treatments. Substantially higher number of plant population was observed under climate smart agriculture practices as compared to that of conventional practices. The plant population was highest under climate smart agriculture medium (55555.56) followed by climate smart agriculture high and low with equal population (53819.44). The ear number is positively associated with plant density. Highest number of ears was observed under climate smart agriculture medium (54816) followed by climate smart agriculture high (54166. While, least number of ear was observed in conventional farmers' practice. The result coincide with Adhikari *et al.* (2004), where he get 53,333 plants ha^{-1} under 120 kg N ha^{-1} and 44,444 plants ha^{-1} for supplied 60 kg ha^{-1} of N. Govind *et al.* (2015) also recommended higher doze of fertilizer application for high density planting, Maize hybrids produced the higher grain yield with 200:60:40 kg NPK/ha during winter in Terai. The tillage practice not only had affected the plant population but had also affected ear ha^{-1}. Integration of promising varieties with zero tillage, site specific nutrient management, cover cropping, mulching and scheduled irrigation practiced in climate smart agriculture practice plays synergetic effect for soil improvement which has direct impact on crop growth, establishment and retaining higher plant density per hector. Baker, (1975) reports that climate smart agriculture practices are attributable to soil type, fertility level, variety and other environmental conditions and fertile soils accommodate higher populations per hector than poor soils. Both plant density and formation of ear per hectare determine the grain yield Reports by Musick (1994), de Almeida *et al.,* (1998), Widdicombe and Thelen, (2002) and Bertoia (2000) revealed increment of yield by increasing plant population up to a certain limit usually above 70,000 plants ha^{-1} under climate smart agriculture and management practices

Thousand grain weight

There was significant variation among thousand grain weight under different treatments. The grains were found bold with higher test weight under climate smart agriculture practices and improved irrigated condition than in conventional practices at farmers' field.

Biomass yield (ton/ha)

Due to adequate supply of water and nutrients luxuriant vegetative growth of plant was observed under climate smart agriculture practices than in conventional farmers' field. Significantly higher biomass was produced under climate smart agriculture high (32.46) followed by climate smart agriculture medium (26.49) (Table -2). There was least biomass production under conventional farmers' field (21.85).

Grain per row

Similar to ear number, grain per row was significantly higher in climate smart agriculture practices (38.8) and improved irrigated low (36.9) as compared to that of conventional farmers' practice (table – 2). The results indicate that plants subjected to water, and nutrient stress tends to have low grain filling than plants supplied with adequate water and nutrient requirements. The significant difference in yield between the full irrigated plants and those stressed indicate that the imposed water stress caused a reduction in the physiological activities of the plant as such the plant could not achieve full growth potential which was exhibited in the significantly in grain filling and yield attributes. This is in tandem with results obtained by Nadanam and Morachan, (1974), Hiraoka *et al.,* (1976), Lazarov *et al.,* (1976), Warrick and Gardner, (1983), Karlen and Camp, (1985) and Averbeke and Marais (1992), who all reported increasing yield with increase in irrigation water supplied

Grain yield (ton/ha)

Grain yield is the sum effect of all the yield attributing traits. Significant variation was observed in terms of grain yield under different treatments. Maximum grain yield (ton/ha) was obtained in climate smart agriculture high (5.45) followed by climate smart agriculture medium (4.74). The grain yield was substantially lower under conventional farmers' practice (4.07). Kassam *et al.,* (2009) indicated that minimal soil disturbance through no tillage or reduced tillage ensures a favorable proportion of gases for root respiration, moderate organic matter oxidation, good porosity for water movement, and limited re-exposure to weed seeds and their germination, which may enhance crop growth and final grain yield. Hammad *et al.,* (2011), had recorded grain yield of 4.67 t ha^{-1} in combination of 6 number of irrigations with 150 kg ha-1 fertilizer application. Likewise, no-till agriculture is considered well for soil fertility, with benefits in terms of adaptive capacity and food security because it contributes to increased yields. In addition, research shows evidence of yield and soil improvements in humid tropical and temperate ecosystems where minimal and no-tillage practices are applied (Rasmussen 1999; Bronick and Lal 2005). The advantages of tillage options may include increased crop establishment, improved infiltration and reduced runoff, the principles behind the tillage are also to increase soil porosity and to manipulate surface roughness to improve water intake (Cogle *et al.,* 1997). When crop residues are retained on the surface, it requires at least three years before the beneficial influence on grain yields are obtained. As reported by some researchers (Lal, 1976; Kang & Yunusa, 1977) grain yield response to minimum tillage when the residues are retained depends on the gradual build-up of soil fertility. This research experiment is in line with previous studies (Pretty 2000; Altieri 1999) showing that farmers benefited through increased yields of maize following the use of cover crops. In addition, mixing no-till farming and cover crop usage with herbicides has been found to reduce leaching and improve yields (FAO 2010). Research has shown that the greatest benefits of implementing improved cropland management practices under CSA are higher and more stable yields, increased system resilience, enhanced livelihoods, greater food security, and reduced uncertainty (Conant 2010; Wood fine 2009; Thomas 2008).No-till, or a reduced proportion of the area needing tillage, requires less input of energy per unit area, per unit output, and lower depreciation rates of equipment. Over time, less fertilizer is required for the same output (Lafond *et al.,* 2008). Production costs are thus lower, thereby increasing profit margins as well as lessening emissions from tractor fuel (Hengxin *et al.,* 2008). Better soil protection by mulch cover minimizes both runoff volumes and the scouring of topsoil, carrying with it seeds and fertilizers. Such losses represent unnecessary cost, wasted rainwater and wasted energy. Their avoidance increases the margin between profits and costs, which formerly, under tillage agriculture, were accepted as ‘normal’ expenses to be anticipated.

CONCLUSION

The introduction of zero tillage in climate smart agriculture practices has been gaining popularity in developing countries as it has been recognized as low cost production technology. Zero tillage substitute labor and reduces cost of cultivation by two to three folds with incremental effect in yield and income of small holders and commercial farmers. Zero tillage also conserves soil health with minimal disturbance in soil structure, porosity and microbial growth. Further, zero tillage ensures spatial nutrient management and moisture retention in root zone causing luxuriant plant growth with higher tillers. Besides, retention of previous crops stubbles increased soil organic matter and fertility thus increasing production and yield. Water management, introduction of legumes as cover crop, mulching and crop rotation are key innovations in climate smart agriculture to cope up environmental stress without compromising yields. In this experiment, integrated climate smart innovations were made in maize crops. The treatment varied from conventional farming system practiced by farmers to gradual advancement in climate smart agriculture practices with slight modification and intervention in each treatment. The yield obtained in Climate Smart Agriculture High (CSH) was significantly higher than in other treatments. It is due to cumulative positive effect of various interventions made. Climate Smart Agriculture High (CSH) differ from Climate Smart Agriculture Medium (CSM) only in terms of Legumes incorporation conserving soil health and restoration of soil fertility. Thus, Climate Smart agriculture high (CSH) which involves simple interventions and altercation in normal cultivation practices has synergetic effect on crop growth, yield and income. Since, small holders whose share on global food production is more than 70% are the major contributors of food availability. Therefore, initiatives to promote zero tillage and climate smart agriculture practices among small holders certainly add value in achieving global food security.

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