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Contents

Effect of Seedling Density and Bed Type on Growth of Elm (Ulmus wallichiana) Seedlings in the Nursery

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ABSTRACT

Ulmus wallichiana is an important multipurpose tree species of the Himalayan region suitable for furniture, leaves are consumed as fodder while as small wood is used as fuel wood. Elm seeds are minute and are generally broadcasted in the nursery beds, thereafter they need to be thinned out or transplanted so that they achieve transplantable height. The study aimed at studying the effect of seedling density and bed type on the growth of Ulmus wallichiana seedlings over a period of two years & was undertaken under All India Coordinated Research Project on Agroforestry at Srinagar centre, India. The seedlings were evaluated in nursery beds, transplant beds and thinned out nursery beds. The study concluded that undisturbed seedling beds with a density of 400 seedlings/m2 recorded maximum height of 1.51m but seedling collar diameter was minimum. Maximum diameter of 9.56mm was recorded in undisturbed thinned out nursery beds having a density of only 100 seedlings/m2 but height recorded was only 1.39m. Transplant beds recorded a height of 1.19m and a diameter of 7.19mm. In the present study it is evident that the seedlings need not to be necessarily transplanted from seedling beds but in the second year if proper density (100 m3) is maintained by thinning, maximum seedling growth in terms of both height and diameter can be achieved.

Keywords *Transplant Beds, Seedling Beds, Thinned Out Nursery Beds, Ulmus Wallichiana*

1. Introduction

Elm belongs to the family Ulmaceae and is distributed in the Himalayas from Kashmir to Uttranchal, India and Nepal within an altitude of 900-3,000m [1].The species is also scattered in Central Nuristan (Afghanistan). In India the species is distributed over the states of Jammu and Kashmir, Uttranchal, and Himachal Pradesh. In the state of Jammu and Kashmir distribution of Elm has been reported in all the districts of Kashmir though their concentration varies from district to district [2]. Elm if allowed to grow attains a great height and girth. Leaves of elm are suitable for fodder, barkyields a strong fibre, useful for cordage and for rope making and sandals. Timber is used for making trays, ploughs, building and fuel. The young shoots are much esteemed as fodder for buffaloes. It is also suitable for furniture, light construction and planking [3, 4]. Due to its multifarious uses the tree has been heavily exploited, as a result of which, the species has become vulnerable [5]. Natural regeneration of the species is very poor due to high incidence of empty seeds, besides seeds of the species are scarcely available and if available are not viable because of their short viability and thus afforestation by artificial means is difficult. Germination of seeds is about 96% if collected at the proper time well before the seeds lose their viability. Seeds of elm are very minute and weigh about 10.14 g per 1,000 seeds [6].

Elm in the beginning is very slow growing and after germination need to be transplanted to transplant beds for another year so that they can attain transplantable height. Since, the seeds are small so they cannot be sown at predetermined spacing in the nursery beds and as such broadcasting is the only method of seed sowing in the nursery. Broadcasting of seeds does not maintain the proper density of seedlings in the nursery beds as a result of which germinating seedlings have to compete for space and nutrients for their growth. The seedlings are kept in the nursery beds for at least 2 years till they attain a transplantable height. For the production of premium quality trees the health and quality of seedlings are essential. Nursery raising of plants should aim at vigorous healthy plants of uniform size. Seedling grade or quality is important, but there is no single parameter which adequately assesses quality [7].

Seedlings planted in the forests or on farmland are produced in nurseries. Bare-root seedlings are grown in nursery beds for two to four years, depending on species and size required, and then dispatched for field planting . The stock may remain in the same seedbed throughout the nursery cycle of production (usually about two years), or after one or two years in the seedbed it may be transplanted into another bed at a lower growing density to produce larger stock. Field grown seedlings and transplants are categorised by age. A 2+0 plant is a seedling that has grown for two years in the same location from seed, while as 1+1 plant is a transplant which has grown for one year in seedling bed and one year in transplant bed[8]. For some species the transplanting process makes the plant more vigorous. Choice of stock type depends on factors such as species, availability, planting method and cost. Whatever the stock type, seedlings should be of the best quality, uniform and healthy.

In order to overcome the problem of slow growth and obtain vigorous and uniform seedlings of Elm in the nursery, an experiment was designed to compare the growth of seedlings in seedling seed beds, transplant beds and thinned out seedling beds so that the technology could be standardized for raising quality seedlings in nursery.

2. Material and Methods

The experimental trial was laid at Shalimar, Kashmir situated at Srinagar, India between 320 17 and 360 58 N latitude and 720 26 and 830 20 E longitude at an elevation of 1,584m and the climate of the region falls under temperate climatic regimes with mean annual rainfall of 660mm and mean temperature of 13.30C. Minimum temperature of the area may drop to -70C in winter months while as maximum temperature may touch to 350C in summer. Soil at the experimental site is silty clay loam in texture, neutral having available nitrogen of 100kg/ha, phosphorus 10kg/ha and potassium 200kg/ha with good water holding capacity. Seeds of Elm after collection in the month of April 2009 were

broadcasted in the nursery beds of size 1m2 maintaining a density of about 400 seedlings. After germination and completion of one year growth in the nursery beds an average height of 0.69m and collar diameter of 3.98mm was attained. After the first growing season in the nursery, plants were trained to a single leader, and lateral branches pruned off 5 cm of the main stem. Thereafter for the next year, 2010 three treatments were designed for evaluation and laid in randomised block design. All the treatments were replicated 20 times. In one of the treatments (T1) earlier density of 400 seedlings/ m2 of nursery beds was maintained while as in other (T2) some seedlings were removed and density of 100 seedlings/m2 was maintained with a spacing of 10x10cm. In treatment T3 the seedlings after being removed from nursery beds were transplanted in transplant beds at a spacing of 10x10cm and as such density of 100 seedlings/m2 was maintained. Seedlings were thinned and transplanted in dormant winter season (December 2009). During the evaluation period (January to December 2010) the seedling beds were regularly watered and weeded and hoeing was also carried out as and when required. The seedlings were evaluated at the end of the growing season in terms of height, collar diameter and biomass. From each plot, five plants nearest the mean stem diameter and height were selected for aboveground biomass measurements. Data was statistically analyzed using Minitab programme.

3. Results

Table depicting data shows the effect of different treatments on the height, collar diameter and biomass of elm seedlings. Bed density significantly affected diameter, height and biomass of seedlings. Differences among various treatments were statistically significant at 5% level of significance. Seedlings kept in nursery beds without transplanting and having a density of 400 seedlings in the nursery beds recorded an average height of 1.51m which was more than the height recorded in thinned out nursery beds (1.39m) and transplant beds (1.19m). Recorded height in seedlings beds was 8.63% and 26% more than thinned out and transplant beds respectively.

Regarding collar diameter it was maximum of 9.56 mm in thinned out nursery beds with a standard deviation of 0.17, followed by 7.19 in transplant beds and 5.37mm in seedling nursery beds. Collar diameter recorded in thinned out nursery beds was 78% more than seedling beds and 33% more than transplant beds. Biomass followed the same trend as that of collar diameter. Maximum biomass significant at 5% level was recorded in thinned out seedling beds (55g) followed by transplant beds (44g). Seedling nursery beds recorded a biomass of only 38g.

4. Discussion

The easiest method to asses quality of seedling is to measure height and stem diameter, which are often well-correlated with later growth in the field [9;10].

Table 1. Growth of Ulmus wallichiana seedlings in the nursery as affected by density in seedling and transplant beds

	Treatment	Density/m^2	Height(m)	Collar diameter (mm)	Biomass (g)
1	Seedling nursery bed	400	1.51	5.37	38
2	Thinned nursery bed	100	1.39	9.56	55
3	Transplanted nursery bed	100	1.19	7.19	44
	Mean		1.36	7.37	45.66
	St. deviation		0.04	0.17	10
	Critical Difference at 5%		0.02	0.11	5.22

Maximum height was recorded in seedling beds because the seedlings were not disturbed besides, when density of seedlings is more the seedlings tend to become tall and thin. Smith reported that results in the nursery confirm the principle that height growth is relatively constant over a wide range of stand densities [11]. Many factors affect the performance of plants in seedbeds, transplant beds and the field. Nursery bed density and seedling grade besides mineral nutrition are two of the most important. In general, average plant size increases as bed density decreases [10], and the percent yield of usable seedlings is frequently higher at lower bed densities [12]. Maximum diameter in thinned out nursery bed is due to the fact that the seedlings were not disturbed during the second year but were given ample space for growth by removing excess of seedlings from the nursery beds through thinning. Seedling nursery beds had a density of 400 seedlings and so cannot compete with thinned or transplanted nursery beds. Seedlings once removed from seedling beds receive shock and on transplantation in transplant beds have to overcome the shock and as such cannot compete with already established seedlings in seedling beds so it is perhaps the reason that seedlings did not get a thicker collar diameter. Transplanting process generally results in a large calliper and a more fibrous root system. The seedlings will have more side branching. The root system on a 1+1 plus the extra storage of food in the calliper and root system will allow the seedling to survive on an infertile sites, compete with other vegetation and give it a better chance of surviving browse damage. On the other hand seedlings kept in beds for 2 years without being transplanted are ready of planting out, production cost is low because seedling has not been transplanted. This stock type will survive in a site that has low competing vegetation minimum levels of animal browsing.

5. Conclusions

Nursery technology for raising seedlings in seedling beds, transplant beds and thinned out beds also play an important role as has been clearly demonstrated by the present investigation. Thus, selection of optimum bed density (density which produces the maximum number of usable seedlings per unit area) and type of nursery bed (Transplant, thinned out and seedling bed) assumes importance for raising suitable nursery crop. In the present study it is evident that the seedlings need not to be necessarily transplanted from seedling beds but in the second year if proper density (100 m3) is maintained by thinning, maximum seedling growth in terms of both height and diameter can be achieved. Transplanting on the other hand may result in fibrous root system but growth cannot be comparable with seedlings in undisturbed beds because they have to overcome the shock of transplantation which needs time.

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Effect of Field Plot Design on the Efficacy of Boom Sprayer

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ABSTRACT

Field performance of the boom sprayer was evaluated at three different plot sizes, three different operating pressures and at three different forward speeds of tractor. Four spraying operations were performed. At the first two sprays only the sucking insects (Jassid, and Whiteflies) were analyzed for mortality as there were no bollworms at that stage. In third and fourth spray bollworms were analyzed for mortality. The experiment was done to find out the effects of pressure and velocity on mortality of white fly, jassid and bollworms and the effect of field size on field efficiency of boom sprayer. The results indicated that increase in velocity decreases the mortality or sucking insects as well as bollworm insects. Best field speed for crop spraying operation was observed to be 4.0 km/h. Working pressure of 400 kPa has a significant effect on insect mortality. For same width of fields, longer the field more the productive time, therefore, more will be the field efficiency of the sprayer. Lower field speed had more sprayer field efficiency than the greater field speed. The reason could be the more time required for turning at field ends to less maneuverability of tractor the operator might had found difficulty in controlling over the tractor holding more wider sprayer mounted behind.

Keywords *Field Plot Design, Boom Sprayer, Cotton Crop and Cotton Insects*

1. Introduction

Agriculture is the major source of Pakistan's economy. Nearly 24% of the Gross Domestic Product and 44 % of the total employment are generated in agriculture. Not only that 44 % of country's man power is engaged in agriculture but also 67.5 % of our population living in rural areas is directly or indirectly associated with agriculture for its living. The estimate of cotton production is about 12.7 million bales for the year 2009-2010. The cotton yield is affected by 8.6 % due to the pest attack in cotton belt. When cotton plants are examined from above, generally only the upper surfaces of leaves are visible. This upper foliage presents such a barrier that only a small proportion of spray applied reaches downwards to reach stems and petioles. Ideally, nozzles need to direct spray upwards and between branches so that some under-leaf coverage is obtained which would be less expected to be washed off by rain. (Tunstall et al., 1961).

Pesticides have contributed to dramatic increases in crop yields and in the quantity and variety of the diet. Also, they have helped to limit the spread of certain diseases. But pesticides have harmful effects

also; like that of injury to human health as well as to the environment. For many reasons, the severity of pesticide hazards is much pronounced in Third World Countries. A number of long persistent organ chlorines and highly toxic organophosphates, which have been banned or severely restricted, are still marketed and used in many developing countries. The misuse of pesticides by concerned individuals, in addition to lack of or weak national controlling plans is behind the outbreak of adverse effects in developing countries (Monsour, 2004).

The operating pressure of any type of hydraulic sprayer critically affects the nozzle's flow rate/discharge and droplet size. Too low pressure result in poor coverage and bigger droplets which are undesirable for contact action type pesticides. Too high pressure on the other hand results in too small droplets which in turn decreases terminal velocity and may result in increased hazards of excessive drift and evaporation. Therefore, the sprayer should be provided pressure gauges so that the desired pressure could be maintained (Hameed and Rehman, 1996). This study has been designed a) to asses the effect of field plot design on the efficacy of designed boom sprayer. b) to check the effect of different tractor velocities and spray pressures on the mortality rate of insects.

2. Materials and Methods

The study was conducted in the cotton field of post graduate agricultural research station (PARS), University of Agriculture Faisalabad. Cotton variety BT-448 was sown at beds with row to row spacing of 0.762 m during cotton growing season of 2010. A 2-hectares field (Figure 1) was divided into three sub fields of different sizes (32.31 m * 228.5 m, 32.31 m * 167.65 m and 32.31 m * 103.04m). An improved drop-pipe boom sprayer designed and developed in department of farm machinery and Power, University of agriculture Faisalabad was employed for the control of cotton insects and pests at four stages of crop growth.

First spray Plolo-500 SC (200 ml/acre) was completed when the crop height was 75 cm. The drop-pipes wereadjusted vertically hanging down from the main boom pipe. Number of sucking insects i.e. whiteflies and jassid, were counted on the leaves both before and after spraying. Three leaves were picked from the three levels of cotton plants (upper, middle and lower) from each treatment block. (Arif, 2001) Jassid and whitefly mortality was calculated 1-day and 7-day after spraying with the following relationship:

$$M = \frac{N - n}{N} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
M = % age insect mortality
N = No. of insects before spraying
n = No. of insects after spraying

Second spray was done on August 15, 2010 in response to serious damage by whiteflies and jassid. Imedaclopride 20 % SL was sprayed at the rate of 100 ml/acre. Average height of a plant was 98 cm. Pest scouting was done just one day before and one day and one week after spraying and mortality of insects calculated using equation 1.

Third spray was done on September 9, 2010. At this stage cotton plants were nearly reached to maturity. The medicine used was Lamda cyhalothrin 2.2 EL. Very small number of sucking insects at this stage were seen which were less harmful at this stage. Only the target insects were American and Spotted bollworms (ABW, SBW). Pest scouting was done just one day before and one day and one week after spraying and mortality of insects calculated using equation 1.

Fourth spray was done on October 17, 2010. Pest scouting was done just before one day and after one day and one week of fourth spraying. Only the target insects were American and Spotted bollworms. The attack of American bollworms again started after the first week of October due to rainfall. Pest scouting was done just one day before and one day and one week after spraying and mortality of insects calculated using equation 1.

A 3×3×3 factor factorial was employed in randomized complete block design to evaluate the effects of three levels of tractor forward speeds (2.5, 4.0 and 5.5 km/h), three levels of spraying pressures (300, 400 and 500 kpa) at three levels of field plot design (32.31 m * 228.5 m, 32.31 m * 167.65 m and 32.31 m * 103.04m) on field performance of sprayer for insects mortality. Statistical analysis was performed with GLM procedures of SAS (SAS, 2002-03).

3. Results and Discussions

The percentage death rate of the insects with a specific pesticide and equipment is known as insect mortality. It was calculated from the pest scouting data before and after the spraying. The mortality of sucking insects was calculated as per leaf basis while for the bollworms; their mortality was determined for each plant basis.

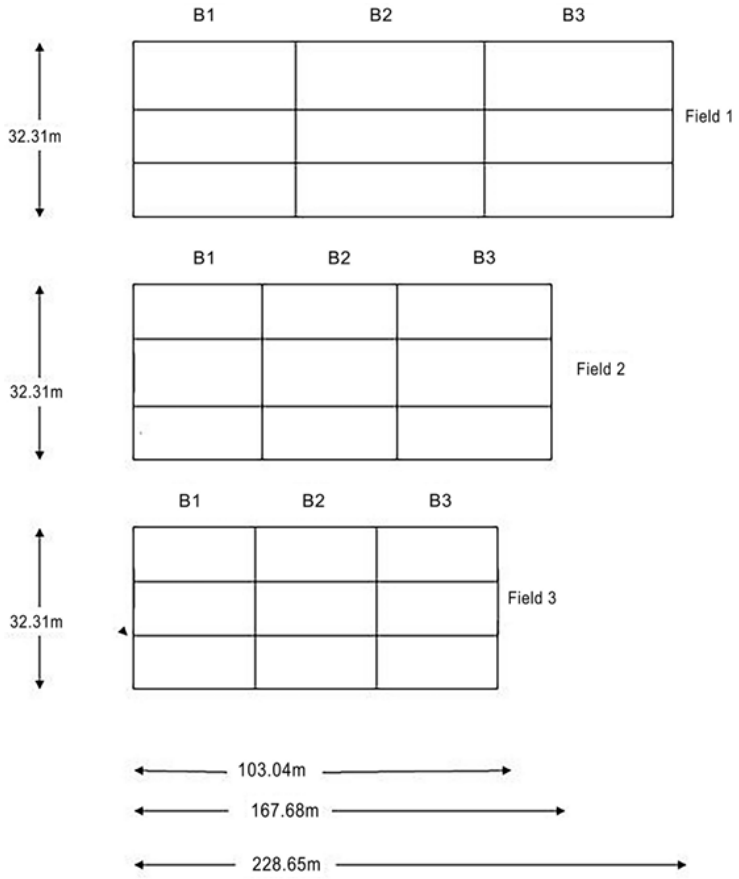

Figure1. Fields Layout at (Post graduate agricultural research station) PARS

Effect of spraying pressure on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of first spray

The effects spraying of pressure on % age mortality of white fly and jassid presented in table 1 showed that mortality rate of white fly were significantly greater at pressure P2 (400 kPa) and P3 (500 kPa) than that at pressure P1 (300 kPa) both after one day and after seven days of spraying. At P3 (500 kPa) droplets would have been so small that might not had enough potential to hit the target insects resulting in low mortality. At P1 (300 kPa) the droplets might have not reached at target. Mortality rate of jassid follows the same trend but were not significantly different after one day of spraying. The % age mortality of white fly at P2 was 70.00 % and 93.00 % after one day and after one week respectively. The % age mortality of jassid at P2 was 71.07 % and 95.00 % after one day and after one week respectively. No doubt P2 and P3 did not significantly differ in mortality rate of white fly; however, P2 resulted in 1.02 times greater in mortality rate than that at pressure P3 after one day. Pressures P2 resulted in 1.06 and 1.04 times greater in mortality rate than that at pressure P1 and P3 after one day. The pressures P2 and P3 significantly differ in mortality rate of white fly after one week. The table 1 also depicted that mortality rate of white fly at P1, P2 and P3 pressures were 1.33, 1.32 and 1.30 times greater and mortality rate of jassid at P1, P2 and P3 pressures were 1.29, 1.33 and 1.38 times greater after one week

than that at after one day.

Table 1. Effect of Pressure on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of first spray

Pressure	White fly		Jassid	
	AOD	AOW	AOD	AOW
P_1	62.11[b*]	83.07[c]	66.81[a*]	86.19[b]
P_2	70.00[a]	93.00[a]	71.07[a]	95.00[a]
P_3	68.81[a]	89.96[b]	68.00[a]	94.41[a]
Mean	66.97	88.49	68.63	91.86
LSD(0.05)	3.33	2.80	5.60	6.79

*Means in each column followed by the same letter are not significantly different at 5 % probability level.

P1 = 300 kPa, P2 = 400 kPa, P3 = 500 kPa, AOD = after one day and AOW = after one week

Effect of Velocity on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of first spray

The statistically analyzed data showed in table 2 indicated that spraying velocities significantly effected mortality rate of both white fly and jassid. The % age mortality of white fly at velocity V2 (4.0 km/h) was 68.55 % and 90.51 % after one day and after one week respectively and the % age mortality of jassid at V2 (4.0 km/h) was 70.55 % and 95.77 % after one day and after one week respectively. Velocity V2 resulted in 1.02 and 1.04 times greater in mortality rate than that at velocity V1 and V3 after one day. The velocities V1 and V3 did not significantly differ in mortality rate of white fly after one week; however, V2 resulted in 1.03 times greater than that at V1. Velocities V1, V2 and V3 did not significantly differ in mortality rate of jassid; however, V2 resulted in 1.05 and 1.03 times greater in mortality rate than that at velocity V1 and V3 after one day. The table 2 depicted that mortality rate of white fly at V1, V2 and V3 velocities were 1.31, 1.32 and 1.32 times greater and in case of jassid 1.36, 1.35 and 1.29 times greater after one week than that at after one day. Too low V1 (2.5 km/h) field speed might not be suitable due to bending of cotton plants for long time and spray exposure might be away from the target. At too high V3 (5.5 km/h) field speed, the spray might have not hit directly to the target due to fast movement of plants with drop pipes.

Table 2. Effect of Velocity on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of first spray

Velocity	White fly		Jassid	
	AOD	AOW	AOD	AOW
V_1	66.63^{a*}	87.77^{ab}	67.14^{a*}	91.77^{ab}
V_2	68.55^{a}	90.51^{a}	70.55^{a}	95.77^{a}
V_3	65.74^{a}	87.18^{b}	68.18^{a}	88.03^{b}
Mean	66.97	88.48	68.62	91.85
LSD(0.05)	3.13	3.08	3.96	4.22

* Means in each column followed by the same letter are not significantly different at 5 % probability level. V1 = 2.5 km/h, V2 = 4.0 km/h, V3 = 5.5 km/h, AOD = after one day and AOW = after one week

Effect of spraying pressure on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of second spray

Table 3. Effect of Pressure on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of second spray

Pressure	White fly		Jassid	
	AOD	AOW	AOD	AOW
P_1	66.11^{b*}	83.66^{b}	66.00^{b*}	85.44^{b}
P_2	69.81^{a}	93.66^{a}	71.55^{a}	94.92^{a}
P_3	68.40^{ab}	93.48^{a}	67.14^{b}	92.88^{a}
Mean	68.10	90.26	68.23	91.08
LSD(0.05)	2.97	3.32	2.71	4.78

* Means in each column followed by the same letter are not significantly different at 5 % probability level. P1 = 300 kPa, P2 = 400 kPa , P3 = 500 kPa, AOD = After one day and AOW = After one week

The results showed in table 3 that more mortality of white fly and jassid were achieved at P2 (400 kPa) followed by P3 (500 kPa) and P1 (300 kPa). It showed that P1 and P3 were less effective than P2 and unsatisfactory for crop spraying operations with newly developed boom sprayer. The % age mortality of whitefly at P2 (400 kPa) was 69.81 % and 93.66 % after one day and after one week respectively andthe % age mortality of jassid at P2 (400 kPa) was 71.55 % and 94.92 % after one day and after one week respectively. No doubt P2 and P3 did not significantly differ in mortality rate of white fly and

jassid; however, P2 resulted in 1.02 times greater in mortality rate of both white fly and jassid than that at pressure P3 after one day. The pressures P2 and P3 did not significantly differ in mortality rates after one week. The table 3 depicted that mortality rate of white fly at P1, P2 and P3 Pressures were 1.26, 1.34 and 1.36 times greater and mortality rate of jassid at P1, P2 and P3 pressures were 1.29, 1.32 and 1.38 times greater after one week than that after one day.

Effect of Velocity on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of second spray

The results showed in table 4 indicated that more mortality of white fly and jassid were achieved at V2 (4.0 km/h) followed by V3 and V1. The % age mortality of white fly at V2 (4.0 km/h) was 68.96 % and 92.03 % after one day and after one week respectively and the % age mortality of jassid at V2 (4.0 km/h) was 69.59 % and 92.00 % after one day and after one week respectively. V1 and V2 did not significantly differ in mortality rate of white fly; however, V2 resulted in 1.03 times greater in mortality rate than that at velocity V1 after one day. The velocities V2 and V3 did not significantly differ in mortality rate after one week; however, V2 resulted in 1.01 times greater than that at V3. No doubt V1, V2 and V3 did not significantly differ in mortality rate of jassid; however, V2 resulted in 1.02 and 1.03 times greater in mortality rate than that at velocity V1 and V3 after one day. The velocities V1, V2 and V3 did not significantly differ in mortality rate after one week; however, V2 resulting in 1.02 times greater than that at V1. The table 4 depicted that mortality rate of white fly at V1, V2 and V3 velocities were 1.31, 1.33 and 1.32 times greater and mortality rate of jassid at V1, V2 and V3 velocities were 1.32, 1.32 and 1.35 times greater after one week than that after one day

Table 4. Effect of Velocity on mortality (%) of white fly and jassid after one day (AOD) and after one week (AOW) of second spray

Velocity	White fly		Jassid	
	AOD	AOW	AOD	AOW
V_1	66.85^{a*}	88.00^{b}	67.40^{a*}	90.00^{a}
V_2	68.96^{a}	92.03^{a}	69.59^{a}	92.00^{a}
V_3	68.51^{a}	90.77^{ab}	67.70^{a}	91.25^{a}
Mean	68.10	90.26	68.23	91.08
LSD(0.05)	2.54	3.43	4.69	5.64

* Means in each column followed by the same letter are not significantly different at 5 % probability level. V1 = 2.5 km/h, V2 = 4.0 km/h, V3 = 5.5 km/h, AOD = after one day and AOW = after one week

Effect of spraying pressure on mortality (%) of spotted bollworms (SBW) and American bollworms (ABW) after one day (AOD) and after one week (AOW) of third spray

The results indicated in table 5 that significantly more mortality of spotted bollworms (SBW) and American bollworms (ABW) were achieved at P2 (400 kPa) followed by P3 (500 kPa) and P1 (300 kPa). The % age mortality of spotted bollworms at P2 (400 kPa) was 71.07 % and 94.07 % after one day and after one week and the % age mortality of American bollworms at P2 (400 kPa) was 72.11 % and 94.74 % after one day and after one week respectively. The table 6 depicted that mortality rate of spotted bollworm at P1, P2 and P3 pressures were 1.26, 1.32 and 1.35 times greater and mortality rate of American bollworm at P1, P2 and P3 pressures were 1.22, 1.31 and 1.42 times greater after one week than that after one day.

Table 5. Effect of Pressure on mortality (%) of SBW and ABW after one day (AOD) and after one week (AOW) of third spray

Pressure	SBW		ABW	
	AOD	AOW	AOD	AOW
P_1	66.11^{c*}	83.66^{b}	68.37^{b*}	83.77^{b}
P_2	71.07^{a}	94.07^{a}	72.11^{a}	94.74^{a}
P_3	68.66^{b}	93.14^{a}	65.44^{b}	92.96^{a}
Mean	68.61	90.29	68.64	90.49
LSD(0.05)	2.39	2.22	3.15	2.67

* Means in each column followed by the same letter are not significantly different at 5 % probability level. P1 = 300 kPa, P2 = 400 kPa, P3 = 500 kPa, SBW = Spotted bollworm, ABW = American bollworm AOD = after one day and AOW = after one week

Effect of Velocity on mortality (%) of spotted bollworms (SBW) and American bollworms (ABW) after one day (AOD) and after one week (AOW) of third spray

The results presented in table 6 indicated that significantly more mortality of spotted bollworms and American bollworms were achieved at V2 (4.0 km/h) followed by V3 (5.5 km/h) and V1 (2.5 km/h). The % age mortality of spotted bollworms at V2 was 68.85 % and 91.25 % after one day and after one week and the % age mortality of American bollworms at V2 was 69.44 % and 91.44 % after one day and after one week respectively. The velocities V1, V2 and V3 did not significantly differ in mortality rate of spotted bollworms and American bollworms after one day and after one week

Table 6. Effect of Velocity on mortality (%) of SBW and ABW after one day (AOD) and after one week (AOW) of third spay

Velocity	SBW		ABW	
	AOD	AOW	AOD	AOW
V_1	68.29^{a*}	89.77^{a}	69.11^{a*}	90.07^{a}
V_2	68.85^{a}	91.25^{a}	69.44^{a}	91.44^{a}
V_3	68.70^{a}	89.85^{a}	67.37^{a}	89.96^{a}
Mean	68.61	90.29	68.64	90.49
LSD(0.05)	3.13	3.65	4.80	6.39

* Means in each column followed by the same letter are not significantly different at 5 % probability level. V1 = 2.5 km/h, V2 = 4.0 km/h, V3 = 5.5 km/h, SBW = Spotted bollworm, ABW = American bollworm AOD = after one day and AOW = after one week

Effect of spraying pressure on mortality (%) of spotted bollworms (SBW) and American bollworms (ABW) after one day (AOD) and after one week (AOW) of Fourth spray

The table 7 depicted that mortality rate of spotted bollworm at P1, P2 and P3 pressures were 1.29, 1.31 and 1.37 times greater and mortality rate of American bollworm at P1, P2 and P3 pressures were 1.25, 1.33 and 1.34 times greater after one week than that after one day. The results indicated that significantly more mortality of spotted bollworms and American bollworms were achieved at P2 (400 kPa) followed by P3 (500 kPa) and P1 (300 kPa). The % age mortality of spotted bollworms at P2 (400 kPa) was 72.03 % and 94.92 % after one day and after one week and the % age mortality of American bollworms at P2 (400 kPa) was 69.74 % and 93.37 % after one day and after one week respectively.

Table 7. Effect of Pressure on mortality (%) of SBW and ABW after one day (AOD) and after one week (AOW) of fourth spray

Pressure	SBW		ABW	
	AOD	AOW	AOD	AOW
P_1	64.25^{c*}	83.03^{b}	67.62^{a*}	84.88^{b}
P_2	72.03^{a}	94.92^{a}	69.74^{a}	93.37^{a}
P_3	68.00^{b}	93.51^{a}	67.70^{a}	91.29^{a}
Mean	68.09	90.48	68.35	89.94
LSD(0.05)	2.84	2.32	2.17	4.81

* Means in each column followed by the same letter are not significantly different at 5 % probability level. P1 = 300 kPa, P2 = 400 kPa, P3 = 500 kPa, SBW = Spotted bollworm, ABW = American bollworm AOD = after one day and AOW = after one week

Effect of Velocity on mortality (%) of spotted bollworms (SBW) and American bollworms (ABW) after one day (AOD) and after one week (AOW) of Fourth spray

Table 8. Effect of Velocity on mortality (%) of SBW and ABW after one day (AOD) and after one week (AOW) of fourth spray

Velocity	SBW		ABW	
	AOD	AOW	AOD	AOW
V_1	68.11^{a*}	89.25^{a}	67.88^{a*}	88.44^{a}
V_2	68.55^{a}	91.44^{a}	69.03^{a}	92.18^{a}
V_3	67.63^{a}	90.77^{a}	68.14^{a}	88.92^{a}
Mean	68.09	90.48	68.35	89.84
LSD(0.05)	3.69	4.65	4.98	5.69

* Means in each column followed by the same letter are not significantly different at 5 % probability level. V1 = 2.5 km/h, V2 = 4.0 km/h, V3 = 5.5 km/h, SBW = Spotted bollworm, ABW = American bollworm AOD = after one day and AOW = after one week

The results of table 8 indicated that significantly more mortality of spotted bollworms and American bollworms were achieved at V2 (4.0 km/h) followed by V3 (5.5 km/h) and V1 (2.5 km/h). The % age mortality of spotted bollworms at V2 was 68.55 % and 91.44 % after one day and after one week and the % age mortality of American bollworms at V2 was 69.03 % and 92.18 % after one day and after one week respectively. The table 8 depicted that mortality rate of spotted bollworm at V1, V2 and V3 velocities were 1.31, 1.33 and 1.34 times greater mortality rate of American bollworm at V1, V2 and V3 velocities were 1.30, 1.33 and 1.30 times greater and after one week than that at after one day.

Effect of field size on field efficiency of boom sprayer

The statistically analyzed data presented in table 9 showed that field efficiency was greatly influenced by the field size. Table 9 showed that sprayer efficiency in field F1 was significantly greater than those of F2 and F3. The field efficiency of sprayer in field F1 was more because of its more length as

compared to the other two fields. Second field had more sprayer efficiency than that of third field but less efficient than first field. Therefore, it can be concluded that for same width of fields, longer the field more the productive time, therefore, more will be the field efficiency of the sprayer.

Table 9. Effect of field size on field efficiency of boom sprayer

Field	Field Efficiency (%)
F_1	74.00[a]
F_2	67.00[b]
F_3	52.92[c]
Mean	64.64
LSD(0.05)	4.46

*Means in each column followed by the same letter are not significantly different at 5 % probability level. F1 = 228.5 m * 32.31 m, F2 = 167.65 m * 32.31 m and F3 = 103.04 m * 32.31 m

Effect of field speed of boom sprayer on field efficiency

The statistically analyzed results showed in table 10 depicted that with increase in field speed, the field efficiency decreased. The reason could be the more unproductive time for turning at field ends which might had been due to less maneuverability of tractor. That's why the first field speed was more efficient than the other two lower speeds. Second field speed was more efficient than third field speed but less efficient than first field speed for field efficiency of sprayer. Similarly third field speed was less efficient as compared to other two field speeds.

Table 10. Effect of field speed of boom sprayer on field efficiency

Velocity	Field Efficiency (%)
V_1	74.00[a]
V_2	64.33[b]
V_3	58.00[c]
Mean	65.44
LSD(0.05)	0.21

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Soil Fertility and Salinity Status of Muzaffargarh District, Punjab Pakistan

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A B S T R A C T

The main objective of this paper is to check the soil fertility and salinity status. For this purpose, a total of 3325 soil samples, collected from all tehsils of Muzffargarh district (from tehsil Muzaffargarh, Jatoi, Kot Addu and Ali Pur), were tested in the Soil and Water Testing Laboratory, Cane Development Cell, Fatima Sugar Mills, Muzaffargarh, Pakistan from 2012 to 2014. Samples were analyzed for soil reaction (pH1:10), electrical conductivity (EC1:10), soil organic matter (SOM), sodium adsorption ratio (SAR) and plant available phosphorus (Olsen-P). The results revealed that pH ranged between 8.5-9.0 in 75 percent of the samples while about 95 percent were normal with respect to salinity(EC < 4 dS/m) and 74 percent were not affected by sodicity (SAR < 15). Soils were poor in organic matter (92 percent samples had less than 0.80 percent OM) and available phosphorus (95 percent samples had less than 15 mg P/kg soil).

Keywords *Soils, Soil Fertility, Salinity, Pakistan*

1. Introduction

Muzaffargarh is one of the most important districts of Punjab from the agricultural point of view. It is located between 29° 6' to 30° 45 'N Latitude and 70° 30' to 71° 48' E Longitude, in the middle of Pakistan between the two famous rivers of the sub-continent, Chenab and Indus. Muzaffargarh district consists of four tehsils Alipur, Jatoi, Kot Addu and Muzaffargarh. Nearly most of the area of tehsil Alipur and some parts of Muzaffargarh tehsil are flooded every year. The district's towns include Khangarh, Rohillan wali, Shaher Sultan, Rangpur, Gujrat, Budh, Mehmood Kot, Sinawan, Thatta Gurmani, Daira Din Panah, Chowk Sarwar Shaheed, Shah Jamal, Mahrpur, Baseera, Wasanday wali, Jalwala, Pir Amir, BindaIshaq, Ehsan Pur, Bakaini, Seet Pur, Murad Abad, Ghazi Ghaat, Karam Dad Qureshi & Douna Alipur and Jatoi. Muzaffargarh region has an arid climate with very hot summers and mild winters; it is exposed to some of the most extreme weather condition in the country, with highest temperature recorded at 54°C (129 F) and the lowest temperature at −1°C (30°F), and an average annual rainfall of about 127 millimeters. The total area of the district of Muzaffargarh is 830 thousand hectares, of which 112.7 thousand hectare is salt affected and 1.17 thousand hectare is water logged (Anonymous 2013). On average 440 thousand hectares can be used for crop production. Wheat, sugarcane and cotton are the main crops grown, rice, jawar, bajra, moong, mash, masoor, ground nuts, maize and oil seeds (rape seeds and sunflower) being grown at a much lower scale. Mangoes, dates, citrus and pomegranate are the main fruits trees grown whereas dates, jaman, pears, phalsa and bananas

occupy a limited area (Anonymous 2013).

Soil fertility status varies with nature of the cropping pattern and management practices. In Pakistan, most of the agricultural lands are nutrient deficient (Anonymous 2008 a).Ahmad and Khan (2006) declared that 75-92 percent soils of Pakistan are deficient in organic matter (0-1 percent), 70-95 percent in phosphates and 20-60 percent soils in potash. It has been found that micronutrients; such as zinc, boron and iron are also emerging as deficient nutrient in soils of Pakistan (Anonymous 2008 b).

In spite of the inherent low soil fertility, crop yield can still be increased by 30-50 percent with the use of balanced fertilization (Anonymous 2006), on the basis of soil tests which is a pre-requisite for applying the right fertilizer at the right dose to optimize productivity. Furrukh et al. (1992) have studied farmers' soil fertility management strategies that are based solely on resources available, namely off counter chemical fertilizers type, land type, cropping pattern, fallowing and cultural practices. This approach however failed to address scientifically the soil fertility problem as it lacked soil testing facilities for an informed decision. The creation of the soil laboratory facility at Fatima Sugar Mills in 2012 has bridged the technological gap that existed in the Muzaffargarh crop production system by providing soil testing services to the community. After 2 years in operation, the objective of this study is to have a stock take of the severity of agricultural soil deficiencies in Muzaffargarh district and to identify the root cause(s) affecting agricultural productivity and thereby to develop sounder fertilization practices and amendments that are more adequate to the individual characteristic of farms.

2. Materials and Methods

This study was conducted at the Soil and Water Testing Laboratory of the Cane Development Cell, at Fatima Sugar Mills Muzaffargarh Pakistan during the period 2012 to 2014. Composite soil samples from tehsil Muzaffargarh (840), Jatoi (670), Kot Addu (1225) and Ali Pur (590) were collected from 0-15 and 15-30 cm depths for crops and vegetables while 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths for orchards. Samples were air-dried, ground and passed through a 2 mm sieve for analysis. Soil reaction (pH) and electrical conductivity (EC) were measured on a 1:10 soil-water suspension using a calibrated pH meter and EC meter, respectively (Malik et al.1984). Samples were also analyzed for organic matter by Walkley and Black method (Cottenieet al. 1979), for exchangeable sodium, potassium, calcium and magnesium extracted in 1M ammonium acetate pH 7.0 and for available phosphorous extracted with 0.5M $NaHCO_3$ pH 8.5 followed by colorimetry (Watanabe et al. 1965).The sodium adsorption ratio and CEC as the sum of bases were computed. To compute the total salt index, the electrical conductivity 1:10 is converted to ECe by multiplying with the factor Saturation

percentage/100 as described by US Salinity Lab. Staff.(Anonymous 1954).

The soil test values were interpreted using the soil evaluation indices proposed by Abrol et al. (1988) for salinity and by Malik et al. (1984) for nutrient status, which are summarized in Table 1:

Table 1. Criteria of parameters used for classification:

(a) Soil Salinity and Sodicity

Status	pH	EC (dS/m)	SAR
Normal (Salt free)	<7.5	0-2	<15
Very Slightly Saline	<7.5	2-4	<15
Slightly Saline	<7.5	4-8	<15
Moderately Saline	<8.0	8-13	<15
Strongly Saline	<8.5	>16	<15
Saline-Sodic	>8.5	<4	≥15
Sodic	>8.5	≥4	≥15

(b) Nutrient Status

Status	Organic matter (%)	Olsen P (mg/kg soil)
Poor	<0.80	0-8
Satisfactory	0.81-1.29	8-15
Adequate	>1.29	>15

3. Results and Discussion

Dissolved salts (electrical conductivity)

Excessive amount of dissolved salts in soil solutions causes hindrance in normal nutrient uptake process either by imbalance of ions uptake, antagonistic effect between nutrients or excessive osmotic potentials of soil solution and or a combination of the three effects (Obaidur Rahman et al. 2010). The

soil analysis data showed that 94 percent of the samples analyzed in district Muzaffargarh were not saline (EC<4 dS/m) and that 74 percent were not sodic (<15). (Table 2). This trend cuts across the different tehsils except for soil sodicity where it appears to be more prevalent at Ali Pur and Jatoi. It is worth noting that, although salinity was not as serious as expected, the high proportion (>50%) in soil having slight to higher sodicity appears to impact most on soil low productivity. Therefore under this condition classical mitigating measures, such as the application of gypsum, can contribute significantly to improve the soil production potential (Suriyan et al. 2011). Regarding the range of EC (Table 3), the minimum value (0.47 dS/m) was observed in tehsil Kot Addu while the maximum value (18.05 dS/m) was noticed in tehsil Muzaffargarh during the year 2012-14. However, higher EC was also observed in tehsil Jatoi (14.50 dS/m) and Kot Addu (17.90 dS/m). Ali Pur tehsil had dissolved salts ranging from 0.60 dS/m to14.27 dS/m. The reason for high accumulation of salts in some places is due to water logging and application of poor quality irrigation water containing soluble salts. (Ayers, R. S. and D.W. Westcot 1985). The practice of irrigating the field with high EC-water (bore-hole) constitutes a limitation to agricultural activity. Yet the low proportion (<10%) of the salinity inflicted soils at Muzaffargarh indicated the low ionic exchange properties of the soils attributable to the sandy texture that is common to the soils in this region. This in turn indicates the poor ability of the soil to retain plant nutrient for crop production. This should be considered in the fertilization practices whereby residual values of fertilizers could not be reckoned with and the fate of excessive doses of fertilizer is lost to ground water.

Soil alkalinity

Twenty six percent of the soils had a pH 7.5-8.5, that are suitable for agriculture. Seventy-four percent of soils had pH > 8.5 which are limiting to agricultural production. These soils are calcareous and the level of exchangeable sodium is often high. Alkalinity problem in soils is due to the indigenous calcareous parent material with typical low organic matter content (Brady, N.C. and R.R. Weil. 2005). Resorting to high doses (as high as 10 tons per acre) of gypsum amendment is not sufficient to reclaim soils having high pH (>8.5) and high sodium content, thus acid and sulphur additions are often warranted (Sherry Combs, 2007). The reclamation can be so expensive that it might not be justifiable. These problematic soils are encountered mostly in areas prone to water logging conditions since as mentioned earlier sandy soils normally have low retention capacity for free ions. Indeed these are mostly common in fields with shallow water table induced by seepage water losses from feeder canals or by upward movement of water by capillary from the two adjacent sub-continental rivers.

Organic matter

Organic matter has a vital role in agricultural soil. It supplies plant nutrient, improve the soil structure, improve water infiltration and retention, feeds soil microflora and fauna, and the retention and cycling of applied fertilizer (Johnston A.E. 2007). Thus it contributes positively to higher crop yields. Over 95 percent of the soils were deficient in organic matter content leaving a meagre fraction of 4.5 percent that had satisfactory levels (Table 2). The low organic matter content is due to an increased rate of decomposition triggered by the high temperature exceeding 45 °C in summer. Burning or fodder use of the plant material remaining after harvest leave very little to replenish the soil in organic matter (Azam et al. 2001). Growers seldom use farmyard manure and green manuring is rarely done due to subsistence farming leaving little scope for such practice. Low productivity also leads to reduced crop leftover that can be returned to the soil. There is therefore a strong need to adopt measures that can improve the soil organic matter status; otherwise desertification is looming at the horizon for many of these soils. (Sieglinde S. Snapp. 2011)

Plant available phosphorus

The results (Table 2) showed that phosphorus availability to plants was satisfactory (above 90 percent) irrespective of the tehsil. 2 to 9 percent of the soils had values above the benchmark of 15 mg P/ kg (Table 3).Poor levels of plant available phosphorus result firstly from its fixation in calcareous soil due to the high levels of calcium carbonate(Ray von Wandruszka, 2006) and secondly to the recurrent application of phosphatic fertilizers below the recommended rates. Current agronomic recommendation rate for NPK is 1.0:0.6:0.4 but presently it is stagnant at 1.0:0.3:0.01(Anonymous 2008 b).

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Table 2. Results of Soil samples analyzed Tehsilwise (in %age)

Tehsil	Dissolved Salts					pH			Organic Matter			Olsen-P(Phosphorous)			SAR		
	Normal	Very slightly saline	Slightly saline	Moderately saline	Strongly saline	<7.5	7.5-8.5	>8.5	Poor	Satisfactory	Adequate	Poor	Satisfactory	Adequate	Normal	Slightly sodic	Sodic
Muzaffargarh	84	13	2	1	0	0	14	86	93	7	0	4	94	2	47	29	24
Kot Addu	72	17	5	6	0	0	21	79	94	6	0	4	93	3	45	30	25
Ali Pur	78	12	6	4	0	0	42	58	98	2	0	2	92	6	38	36	26
Jatoi	76	14	6	4	0	0	26	74	97	3	0	1	90	9	45	33	22

Table 3. Ranges of different soil parameters (Tehsilwise)

Tehsils	pH			EC (dS/m)			Olsen Phosphorous (mg/kg)			Organic Matter (%)			Sodium Adsorption ratio		
	Min.	Max.	S.D	Min.	Max.	S.D	Min.	Max.	S.D	Min.	Max.	S.D	Min.	Max.	S.D
Muzaffargarh	8.06	9.53	0.21	0.82	18.05	1.68	7	21	1.89	0.35	0.92	0.11	2	50	8.00
Kot Addu	7.82	10.24	0.26	0.47	17.90	1.50	6	22	1.94	0.24	0.96	0.12	2	54	7.30
Ali Pur	8.01	9.18	0.27	0.60	14.27	1.95	7	20	2.14	0.40	0.84	0.09	2	45	8.43
Jatoi	7.90	9.03	0.25	0.61	14.50	1.71	7	19	2.09	0.34	0.84	0.11	2	50	8.22

Recommendations - Soil organic matter level and soil fertility status may be increased by green manuring (sesbania, guar, etc.) once in three years. - Inorganic fertilizers (NPK) should be applied in balanced form according to soil test values and their use efficiency can be increased by band placement for row-sown crops.

Recommendations for district Muzaffargarh on the basis of analysis results are given below

Nutrients recommendations for different crops.				
Crops	Fertility status	Fertilizer rate (kg/acre)		
		N	P	K
Sugar Cane	Poor	78	30	50
Sugar Cane	Medium	58	26	37
Wheat	Poor	52	46	25
Wheat	Medium	42	34	25
BT Cotton	Poor	155	65	50
BT Cotton	Medium	140	52	50
Non BT Cottn	Poor	72	35	25
Non BT Cottn	Medium	60	35	25
Rice	Poor	58	33	25
Rice	Medium	48	25	25
Maize (Hybrid)	Poor	80	60	37
Maize (Hybrid)	Medium	65	46	37

Source: Soil Fertility, Survey and Soil Testing Institute, Punjab, Lahore.

(Annexure-I)

Nutrient deficiency extent in soils and fertilizer use efficiency

Nutrient	Percent soil deficiency	Percent fertilizer use efficiency
Nitrogen	100	40-60
Phosphorous	90	15-20
Potassium	50	75-85
Zinc	70	4-5
Iron	70	11-15
Boron	50	6-8
Copper	15	3-5

Source: Anonymous, (2008c). Pakistan Fertilizer Related Statistics. NFDC

Factors contributing to low fertilizer use efficiency

S.No.	Factors	Percent contribution to low fertilizer use efficiency
1	Poor seed bed preparation	10-25
2	Improper seeding	5-20
3	Delayed sowing	20-40
4	Inappropriate variety	20-40
5	Inadequate plant population	10-25
6	Improper fertilizer placement	5-10
7	Imbalanced fertilizer use	20-50
8	Inadequate irrigation	10-20
9	Weed infestation	15-50
10	Insect attack	5-50

Source: Anonymous, (2008c). Pakistan Fertilizer Related Statistics. NFDC

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Climate Smart Management Options for Improving the Soil Fertility and Farm Productivity in the Middle Hills of Nepal

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ABSTRACT

Increasing food demand and climate change pose a major challenge to the sustainability of food production systems and safeguarding environmental health. Nepal's economy is primarily reliant on agriculture which is highly sensitive to climate variability. Key concerns in the middle hills of Nepal include declining soil fertility and soil degradation, changing temperature and precipitation patterns, and pest and disease outbreaks, all of which are affecting productivity, prices, incomes, and ultimately livelihoods. This paper describes some simple, farmer-friendly climate smart management options, and analyses their importance, effectiveness and impacts on improving soil fertility and farm productivity. Simple and widely-adopted sustainable soil management and agronomic practices, which are based on efficient use of local resources, include improvement in preparation and management of farmyard manure (FYM) and compost, systematic collection of cattle urine and its use as a base for botanical pesticide and liquid fertilizer, integrating legumes and fodder crops into cropping systems, small-scale collection of rain and run-off water, and improved water use efficiency. These practices have resulted in a statistically significant increase in soil organic matter levels, and have improved soil fertility and structure, workability, and moisture characteristics. Soil organic matter reached a mean of 3.77% from 3.32% after adoption of sustainable soil management practices over the period of 1-3 years in 337 farm sites. The nitrogen content of topsoil significantly increased overall (0.17% to 0.2%) and in 3 of 5 time series. Similarly, nitrogen content of improved FYM significantly increased in 3 of 5 series and overall on 350 farmer's fields over a period of 1 to 3 years. 18.6 kg additional N was annually gained from a mature cattle with improved farmyard manure management techniques and systematic collection of urine. Additional benefits include enhanced soil carbon storage, and improved crop resilience to changes in weather patterns. Adoption of these practices has contributed to increased productivity, enhanced income, improved food security, and a beneficial impact on the workload of women.

Keywords *Climate Change, Food Security, Farmyard Manure, Soil Fertility, Sustainable Soil Management, Soil Organic Matter*

1. Introduction

The most prominent current challenges of the Nepalese agriculture sector are achieving food security and responding to climate change. Food security and sustainable agricultural production, linked to economic growth, livelihood improvement and poverty reduction, are central to the new Agriculture Development Strategy (ADS, 2013). In many areas of the world, where agricultural productivity is already low and means of coping with adverse events are limited, climate change is expected to reduce productivity and make production more erratic (Stern, 2006; FAO, 2010).

Decreased rates of farmyard manure (FYM) application (Shah and Schreier, 1991), poor soil nutrient and water management, inadequate replacement of nutrients removed in harvested materials or loss through erosion, leaching and gaseous emissions, has caused decline in soil organic matter (SOM) levels and soil fertility (Kaini, 2004). Jaishy and Subedi (2000) found SOM levels were low in about two thirds of 9,800 arable topsoils sampled throughout Nepal. Total nitrogen (N) was also low in about half and available phosphorous (P) and potassium (K) in about one third of all samples. Consequently, production of major cereals has been virtually stagnant over the past 15-20 years and the national average yields of maize, wheat and rice are well below the attainable and experimental yield - indeed, they are well below those reported in neighbouring countries (Kaini, 2004).

Sustainable soil management received strong support at the Rio Summit (1992), in Agenda 21 (UNCED, 1992), UN Framework Convention on Climate Change (UNFCCC,1992), and Kyoto Protocol (UNFCCC, 1998). These conventions recognize the importance of protecting and restoring soil resources (Barford., 2001) and of strong links between soil degradation and desertification, loss of biodiversity, threats to food security, increasing poverty, and increased risk of accelerated greenhouse effects and climate change (Komatsuzaki and Ohta, 2007).

Agriculture is both a victim of climate change and a significant cause. Agriculture is directly responsible for 10-12% of human-generated greenhouse gas (GHG) emissions, excluding emissions resulting from fuel use and fertilizer production. If these, plus forest clearance for farming, are included, agriculture is responsible for a much greater share of global emissions. Increasing food production without further increasing GHG emissions from agriculture makes this challenge all the greater (Pye-Smith, 2013). In this scenario, climate smart agriculture sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation) and enhances achievement of national food security and development goals (FAO, 2010).

2. Climate Smart Farm Management Options

The Swiss-supported Sustainable Soil Management Programme (SSMP)/HELVETAS Swiss Intercooperation is promoting different agricultural practices since 1999 in the mid-hills of Nepal (Figure 1). The major objective of this paper is to assess these agricultural practices from the perspective of climate smartness, and impacts on farm productivity and resilience. It also assesses the effect of these agricultural practices on soil fertility, farm productivity and income, and reducing women's workload.

How climate smart these agricultural practices are, is assessed based on farmers' perceptions and experiences, and by the analyses of the data obtained from on-farm monitoring of nutrient contents of farmyard manure (FYM), topsoil samples, and soil organic carbon (SOC) surveys. On-farm research studies, thesis research, farmer-led experiments, farmer case studies and various impact studies undertaken by SSMP further verified the findings. Related works were reviewed to supplement the findings.

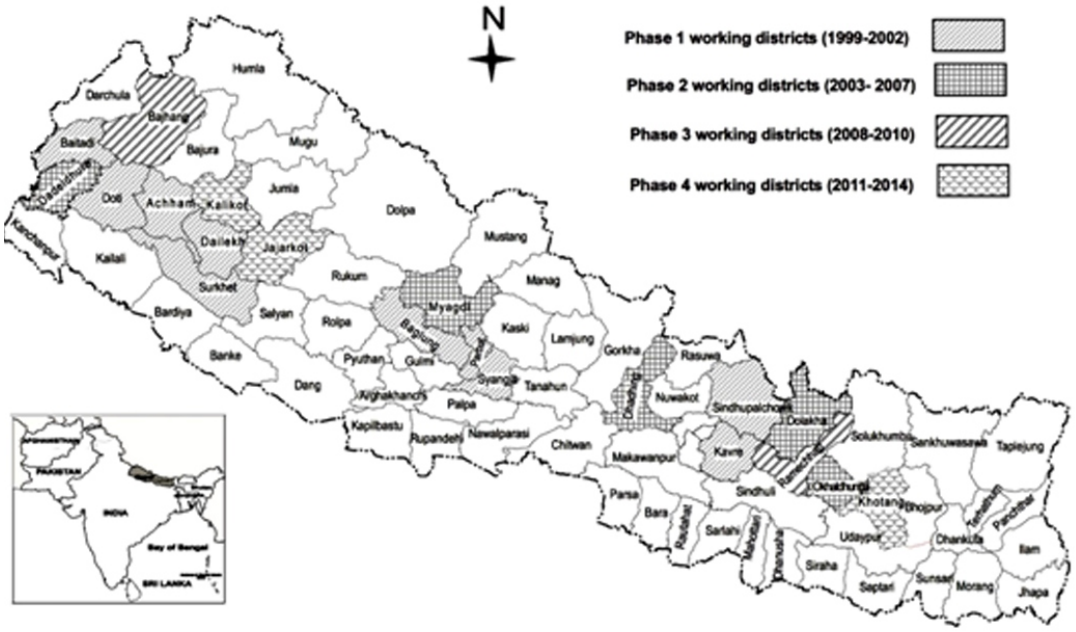

Figure 1. Working Districts of SSMP over its Four Phases

3. Soil and Water Management

3.1. Improving FYM Quality and Retaining Fertilizer Value of Cattle Urine

A mature cow/buffalo under normal mid-hill farming condition produces 1,825 kg fresh dung and 1,460 litres urine per annum (Subedit et al., 2010). The majority of N (up to 97%) that is ingested by cattle is excreted in the form of urea and organic N in urine and faeces (McCrory and Hobbs, 2001). The urea form of N is highly volatile and losses from urine are faster and higher than from faeces. To maximize N retention in urine and FYM, it is important to minimize losses from ammonia emission and nitrate leaching during storage and land-spreading (Figure 2).

Figure 2. Traditional method of FYM storage: Both FYM and urine isn't systematically managed and used

Figure 3a. Improved management practice: FYM heap protected from sun xposure, rainfall and leaching

Improved FYM management techniques involves careful collection, layering and moistening of raw materials, shading the heap from sunlight to minimize N-volatilization, protecting the heap from rainfall to reduce leaching and erosion, no drying of FYM before carrying to the field and immediate mixing into soil, and systematic collection and use of cattle urine as a liquid fertilizer and a base for botanical pesticide (Figures 3a, 3b).

Figure 3b. Systematic collection of cattle urine

Evidence of Improvement from FYM Analysis Results Monitoring of N-content in FYM before and after improved practices were introduced to 350 farmers' fields over a period of 1 to 3 years showed a significant but inconsistent improvement in FYM quality. Increase in N-content of FYM after adoption of improved technique was substantial and significant in 3 of 5 series, and overall (Figure 4). The largest increase was for the series starting in 2000 but this may be exaggerated by unduly low pre-adoption values. Adoption effects in the series 2003-2006 were also positive, but were smaller and non-significant. Systematic collection of cattle urine added a significant amount of N (Table 1).

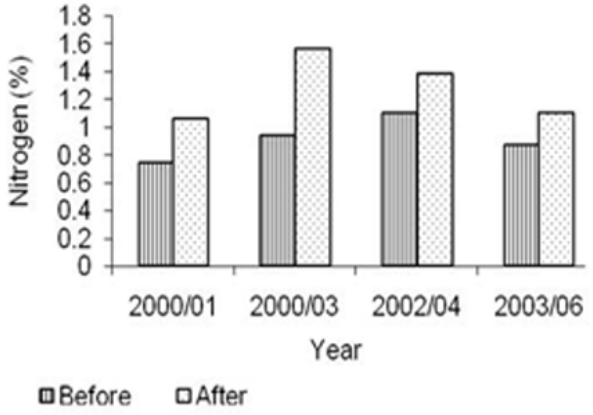

Figure 4. N-content in FYM before and after adoption of improved management practices

Table 1. Comparison of N gain from FYM and cattle urine - with and without improved management techniques

From FYM, N gain/year		Additional N gain/year	From cattle urine, N gain/year		Additional N gain/year
Traditionally managed	Managed with improved techniques	Managed with improved techniques	Without systematic collection	With systematic collection	With systematic collection
15 kg	21 kg	6 kg	4.2 kg	16.8 kg	12.6 kg

3.2. Composting and Crop Residue Management

Farmers are coached to compost on-farm, using crop residues and vegetation from terrace raisers and other farm areas as livestock bedding which is later incorporated into the FYM or compost pits, and to avoid biomass burning and uprooting of legumes. This has helped to reverse the situation of continued biomass removal from soils and to supplement SOM and plant nutrients.

3.3. Integrated Plant Nutrient Management System (IPNS)

IPNS is a holistic approach that integrates all components of soil, plant and nutrient management to achieve higher crop yields and improved soil fertility. The Farmer Field School (FFS) approach was adopted to disseminate the concept of IPNS. Evaluation of 54 FFSs recorded an increase in crop yield of 26%. The results of soil analyses showed an increase in soil fertility, particularly SOM, N, P and K as compared to the base year over a 3 year period (Regmi et al., 2005).

3.4. Preparation and Use of Botanical Pesticides for Managing Crop Pests

SSM options for insect pest and disease management include environment-friendly preparation of urine-based botanical pesticide, crop rotation, mixed cropping and measures that are based on local resources, knowledge and skill. Cattle excreta, both urine and FYM, are mixed with milk to control diseases and insects. Different plants, such as Justicia adhatoda, Artemisia vulgaris, Eupatorium adenophorum, Azadirachta indica, Melia azedarach, Tagetes erecta, Urtica dioica, Acorus calamus etc., that possess pesticidal properties are used to prepare botanical pesticides.

Figure 5a. On-farm research trial on botanical pesticide for managing crop pests

Figure 5b. Farmer-led experiments on botanical pesticides for managing crop pests

On-farm studies and FLEs (Figure 5a and 5b) proved the effectiveness of bio-pesticides in managing insect pests and diseases (Table 2) with no or minimum damage to the local agro-ecosystem. Bio-pesticides often have an ameliorating effect on the plant-soil environment and beneficial organisms, supplying several essential nutrients, adding organic matter to the soil, and acting as a plant tonic (i.e. cattle urine contains up to 1% N), thus enhancing crop growth and production.

Table 2. Effectiveness of various botanical pesticides in controlling crop pests: results from farmer-led experiments

Insect pests or diseases	Botanical pesticides	References
Late blight (tomato, potato), fruit fly (cucumber), borer (tomato, brinjal)	Urine-based botanical pesticide: 10 kg each of Artemisia vulgaris, Justicia adhatoda, Eupatorium adenophorum, Melia azedarach mixed with 4 litres urine and 4 kg fresh FYM, fermented for 30 days.	Bodhraj Aryal, Farmer, Syangja
Caterpillar, aphid	1 kg stinging nettle soaked in 8 litres water for 12 hours in summer and 24 hours in winter, applied within 24 hours of preparation.	Keshav Sharma, Farmer, Syangja
Red ant	500 gm stinging nettle soaked in 1 litre water for 24 hours.	R.B. Siris and P.B. Naisa, Farmers, Baglung
	Green chilli (3 fruits) ground and mixed with 1 litre water, again mixed with 2-3 litres soap-water and 200 gm of ground Artemisia vulgaris shoots mixed together, applied after mixing with water in ratio 1:3-1:5.	Purushottam Lamichhane, Farmer, Syangja
Viral diseases	Cow milk mixed with 4-5 part of water and sprayed at 7-15 days interval.	B.B. Thapa, Farmer, Baglung

3.5. Mulching/Cover Crops

Farmers and stakeholders in the programme districts perceived mulching as effective in conserving soil moisture in times of drought, and suppressing weed growth. It is most commonly undertaken in seed beds and for crops like potato, cucurbits, ginger and turmeric. Mulching creates a conducive

environment for soil microorganisms, adds to the SOM reserve, and often improves quality of produce. It is effective in reducing evapotranspiration and increasing crop growth and yield (Allen et al., 1998).

3.6. Water Management Strategies

Farmers in the programme districts have experienced a complete lack of or late occurrence of winter rain, and more intense but less frequent monsoon rain. In one recent survey, 100% of respondents reported increased drought conditions and 95% perceived decreased frequency but increased intensity of rainfall. The rainfall records (1999-2008) also verified the farmer's perceptions. Since the mid-hill farmers almost entirely rely on rainfall for their crops, water management strategies are essential to ensure survival of both winter and summer crops in water-deficient periods.

a. Water Collection Pond

Waste/grey water, surface and roof run-off water can be collected and led to small plastic or earthen ponds at household level, from where water is provided to nearby cash crops during droughty periods (Figure 6a, 6b). These water harvesting technologies have been effective in reducing risks associated with water shortage in the mid-hill region.

Figure 6a. Waste water from drinking water tap collected in plastic-lined pond to feed plants next to the pond

Figure 6b. Silpaulin-lined water harvesting pond that accumulates runoff water channeled via a plastic-lined canal

b. Irrigation Methods to Improve Water Use Efficiency

Proper and timely water application method, such as drip irrigation, has been identified as one of the best methods to increase water use efficiency. It requires less water than flooding or sprinkling. Khanal et. al. (2013) reported that drip irrigation, as compared to conventional (bucket) irrigation, resulted in 31 % water saving in cauliflower, and increased cauliflower production/area by 46% with the same source of water. Moreover, average production per plant increased by 14%, it reduced irrigation labour costs by 40% and that for weeding and earthing-up by 33%. Ngigi (2009) also reported that shifting from surface irrigation to drip irrigation increased irrigable area by 200%, improving irrigation efficiency by between 25 and 75% using the same volume of water. Regmi et al. (2009) also reported that the local communities in Kaski district of Nepal found drip irrigation saved water, improved yields and reducinged losses during droughts, thereby combatting water shortage. Similarly, sprinkling on coffee plants induced flowering when the rain failed in the flowering season, and sprinkling warm water on plants in coffee nurseries maintained heat.

4. Crop Management

4.1. Inclusion of Legumes into Cropping System

Figure 7. Integrating cowpea into the cropping pattern

Legumes improve N levels in cultivated soil through biological N fixation and scavenging residual soil N, making it available for subsequent crops. Legumes also supply organic matter to soil, suppressing weeds and breaking pest cycles (Peet, 1996; Magdoff, 1998). Growing legumes along with cereals leads to nutrient recycling. Legumes are prolific leaf shedders, and act as a natural manure to conserve soil moisture and maintain soil fertility (Tiwari, 2001). SSMP strongly encourages inclusion of legumes into the cropping system as a sole crop (Figure 7), as a mixed, relay or catch crop, as a cover and green manuring crop, in mixed cropping systems and as forage crops to improve livestock nutrition. It also provides additional cash income for farmers, and compensates the farmers in case the

major crop fails.

4.2. Growing Drought Tolerant Crops/Cultivars

Some crops and cultivars can withstand drought conditions better than others, and thus reduce the risk of total crop failure. Grain legumes, like horse gram and rice gram can better withstand drought condition relative to other grams and legumes. Some cultivars of rice available in Nepal, such as Sukkha Dhan 1, Sukkha Dhan 2, Sukkha Dhan 3, Radha 4, Radha 7, Radha 11, Bindeshwari, Janaki, Makawanpur 1 are recommended for rainfed conditions, and the wheat variety WK 1204 and maize variety Deuti are reported to be relatively drought tolerant. The nature of such crops and varieties indicates that these are not only important for the food security of people living in harsh and difficult terrain but also for those living in other areas which are prone to the adverse effects of climate change.

4.3. System of Rice Intensification (SRI)

One aspect of SRI is the alternate wetting and drying of soil during the rice cropping season rather than continuous flooding. Cooper et al. (2013) reported that flooded rice consumes nearly 40% of all irrigation water. It also produces about 10% of all methane produced by human activities; methane is 25 times more potent than carbon dioxide as a GHG. Allowing the soil to dry out intermittently lets air in, preventing build-up of anaerobic bacteria responsible for methane production. SRI has shown reductions in methane emissions by up to 50%, and reductions in water use by up to 40%. SRI brings immediate benefits to the farmers in terms of increased yield, while building long-term resilience by reducing the amount of water use, reducing emissions of GHG, and sequestering carbon in the soil.

5. Agro-forestry

5.1. Fodder and Forage Crops

Fodder and forage crops provide livestock with improved feed, re-cyclable nutrients, and builds resilience of local agro-ecosystems. SSMP promotes planting of both fodder and forage crops on terrace risers or ridges, wasteland around the farm (which often accounts for 25% of farm areas), and for inclusion in crop rotations (Figure 8). It also encourages stall feeding and reduces women's workload, significantly decreasing time and energy in collecting fodder. It also reduces evaporation and provides biomass for fuel, binds soil, thereby protecting land from erosion, and acts as a home for beneficial insects and birds.

Figure 8. Forage/fodder production on terrace risers

Cooper et. al.(2013) also reported that fodder and forage improves soil structure and fertility, thus rain soaks into the soil more readily resulting in water table replenishment (especially in desert and dry areas), thereby making water more accessible to plants, livestock and people. Other advantages include increasing the resilience of farming systems to extreme weather events, diversifying sources of food and income, protecting land and water resources, and sequestering carbon in the soil, root and biomass. Regmi et al. (2009) also found that the farmers were able to cope with the invasion of new grass species by growing fodder and forage, which also improved resilience to climatic stresses like drought and flooding Effect of Climate Smart Practices on Soil Fertility

337 farm sites were monitored before and after SSM practices in terms of SOM and topsoil nutrient contents. An increase in SOM was reported in each of the time series (Figure 9).

Wilcoxon comparisons showed significant increases in soil N overall and in 3 of 5 individual time series (Table 3). The topsoil N content increased in parallel with SOM, but the effect was slightly less consistent, with significant increases recorded overall and in 3 of 5 time series. The effect on available P in topsoil was inconsistent, with significant increases overall and in 2 series, and insignificant decreases in the other 2 series.

There were significant decreases in soil K overall and in 3 series, with a small but insignificant increase in another one. The decrease may be exaggerated by inflated pre-adoption values. However, a decrease was also reported in other series, suggesting that the effect is real. Soil pH values varied little, with insignificant effects from improved practices.

Another study undertaken in four districts during 2009-2010 revealed that the effect of soil management on SOC were most marked in the 0-15 cm horizon, but continued to be significant well

into the subsoil. SOC in topsoils treated with SSM practices was similar to those under forest, although the forest subsoil had substantially but insignificantly higher levels of SOC. SOC levels were significantly higher in the treated soils than in the non-treated topsoil, and substantial differences continued into the subsoil but were less significant. N is the major nutrient associated with SOM and its pattern was similar to that of SOC, with significantly higher content in the treated soils, particularly in the topsoil (Dahal and Bajracharya, 2012).

Since SOC levels are very sensitive to soil management practices, SSM technologies clearly and significantly contribute to increased SOC. Several long-term studies have also shown the benefits of manuring, adequate fertilization and crop rotation in maintaining productivity and in increasing carbon input into the soil (Mitchell et al., 1996; Reeves, 1997). Two randomized long-term trials comparing organic and conventional farming practices for over 20 years showed remarkable higher carbon contents in organic plots. Evidence from other research (eg. Grandy et al., 2007; Hepperly et al., 2006) also reveal that climate smart management options as described in this paper can sequester more carbon into the soil.

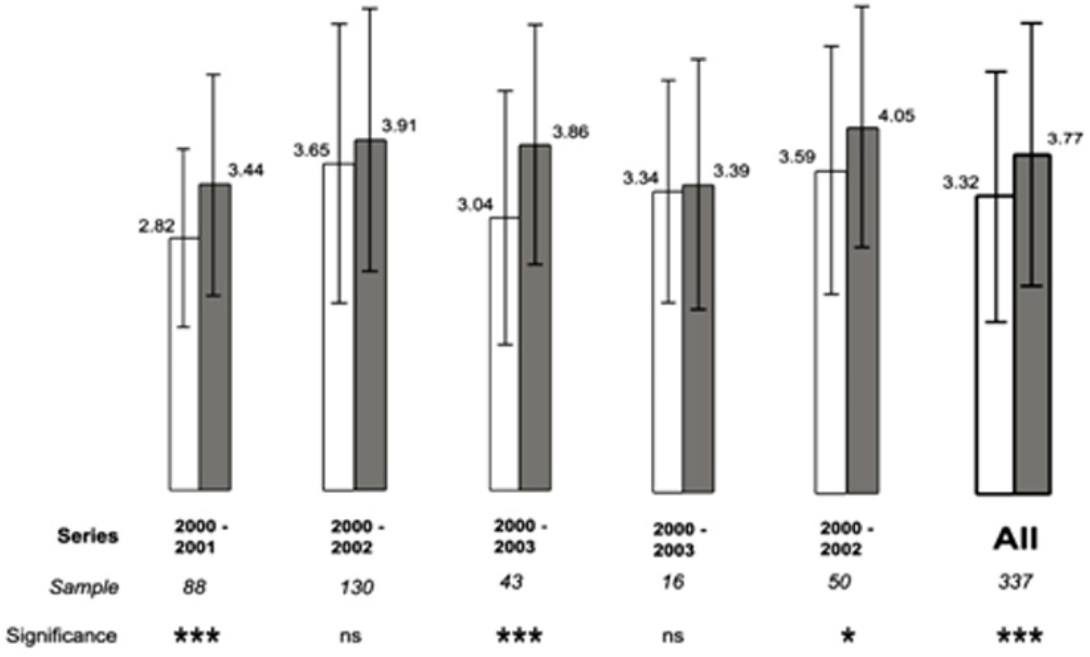

Figure 9. Effects of climate smart practices on soil organic carbon in monitored soils

Table 3. Effect of SSM technologies on nutrient fertility attributes in monitored topsoils

Series	Duration (year)	n	Total N (%)			Available P (mg/kg)			Available K (mg/kg)			Soil pH		
			Start mean	End mean	Increase % & significance	Start mean	End mean	Increase % & significance	Start mean	End mean	Increase % & significance	Start mean	End mean	Increase % & significance
2000-2001	1	88	0.14	0.18	25***	26.21	39.02	49***	481	388	-19**	5.99	5.94	-1ns
2000-2002	2	130	0.19	0.2	4ns	35.37	36.21	2ns	472	501	6ns	5.94	6.04	2*
000-2003	3	43	0.16	0.23	43*	21.59	17.64	-18ns	468	373	-20*	5.41	5.94	10***
2002-2005	3	16	0.18	0.17	-6*	26.88	24.46	-9ns	363	309	-15ns	5.87	5.74	-2ns
2003-2006	3	50	0.18	0.2	12**	28.73	37.51	31**	334	235	-30**	5.77	5.67	-2ns
All	1-3	327	0.17	0.2	16***	29.77	34.16	15*	448	404	-10*	5.85	5.93	1ns

Significance of difference between pre- and post-SSM means (***p <0.001, **p <0.01, *p <0.05, ns p >0.05).

Climate smart agricultural practices include the application of organic manure, biological pest control, legume integration, mulching, and crop rotation, make the best use of local resources, and are environmentally sound (Muller-Lindenlauf, 2009). These practices also assist in reducing the emissions from mineral fertilizer production, which are reported to contribute 1% of anthropogenic greenhouse gas emissions (FAOSTAT; EFMA; Williams, 2006).

Climate Smart Practices: Improving Farm Productivity and Income

The practices described in this paper contribute to increased production of cereals, seasonal and off-season vegetables and cash crops, thus increasing income and food security. Many farmers who have been adopting such practices over the past 5 years have doubled the yields of cereals, vegetables and cash crops (SSMP, 2010b). Adoption of SSM practices has resulted in better soil aggregation and easier tillage, decreased crusting and clodding, and increased moisture availability. On average, adoption of such practices has increased crop yields by up to 30% as compared to traditional practices. Some farmers mentioned improved crop yield in dry years.

A number of factors are responsible for increased crop yield; improved SOM levels and soil structure, and increased nutrient supply from organic sources. The increase in SOM improves crop yield and conserves water. Potential crop yield increases of about 12% for every 1% of organic matter have been reported (Magdoff, 1998). Quiroga et al. (2006) found that crop yields in similarly textured soils depend on total SOM content and an increase in SOM significantly increases nitrate availability.

Climate smart management options, such as legume integration, FYM improvement, systematic collection &and use of cattle urine, combined with integrated livestock production increases the SOM, thereby increasing the water capturing capacity of the agricultural system and lowering the risk of soil erosion. Hence, the risk, of yield losses by extreme weather events is also lowered (Lotter, 2003). Since

these practices do not rely on external inputs, it increases the agricultural productivity and livelihoods of rural communities who have no or little access to inputs, It can promote food availability and increase the income of small scale farmers (Zundel et al., 2007; FAO 2009). A growing demand for organically produced food can offer access to premium prices and hence higher income (Willer et al., 2009).Impact of Climate Smart Options on Women'S Workload

Increasing outmigration of males from rural areas in search of gainful off-farm employment has resulted in an increased workload for women, the feminization of the agriculture sector. Agricultural technologies/practices need therefore to pay due consideration to this major social change.

Initially, adoption of improved FYM management practices and cattle urine collection, demand some additional labour, but it is observed that in the long run, it significantly reduces workload in terms of collecting materials, cleaning cattle-sheds, carrying manure to field (well-prepared manure is lighter), and land preparation. Field studies indicated that after adoption of such improved practices, often with little capital outlay, men have started helping with work, such as FYM management, urine collection and bio-pesticide spraying, tasks previously considered as women's responsibility, especially in remote rural areas. This uptake by men is encouraged by improving the cattle-shed design for easier urine collection (through better drainage and piping the urine to the pit or tank), and the use of a manuring fork to simplify collection. Other practices that have reduced women's workload include: promotion of on-farm fodder and forage, integrating legumes into the cropping system, water collection and conservation strategies, and composting (Bishwakarma, 2013).

Mainstreaming Climate Smart Practices in Governmental Policies and Programmes

Recent policies and programmes of the Government of Nepal in regard to adoption and promotion of climate smart agricultural practices are promising.

Recognition and internalization of climate smart practices as sustainable soil and crop management strategies by the Ministry of Agriculture Development and its reflection in policy and programmes: support is now provided to farmers in 33 districts outside the current SSMP-working districts for promotion of improved cattle-sheds and FYM management.

Establishment of Agriculture, Forestry and Environment Committees (AFECs) at the village level and mobilization of locally-developed Experienced Leader Farmers (ELFs) as extension agents, all of whom have been trained in these climate smart technologies.

Mandate from the Ministry of Federal Affairs and Local Development to allocate at least 15% of the

VDC grants for sustainable agricultural technologies - the VDC is the lowest rung of the administrative structure in Nepal.

Increased focus on promotion of organic products.

Recognition of organic manure as a fertilizer (Fertilizer Act 2001), and provision of subsidies to establish organic fertilizer factories, and support reduced prices of bio-fertilizers.

Climate Change Policy (2011) and the framework on National Adaptation Programme of Action (NAPA) and Local Adaptation Plan of Action (LAPA) have also focused on formulating local adaptation plans for the agriculture sector.

6. Support Needed for Farmers

In the context of a global and competitive market economy, increasing pressure on agricultural production, ever-increasing outmigration of youth, and food security and sustainable land management, Nepalese farmers need political, economic and social commitment and incentives to adopt climate smart and sustainable soil management strategies. Smallholder farmers require direct incentives to encourage the adoption of climate smart management options and income-generating production technologies.

Supporting cattle-shed improvement is a good strategy to substitute chemical fertilizer and encourage farmers to best use locally available resources. Return on investment for a simple redesigned-cattle-shed, costing NRs. 7,000-12,000 (approx. $70-120), is covered within a short period as an additional 19 kg N derives from a single cattle each year - thus such investment is both environmentally and financially sound.

7. Conclusions

The agricultural sector in Nepal must become climate smart to successfully tackle the current challenges of food security deficits and climate change. The practices described here are climate smart options, which increase farm productivity, strengthen farmer's resilience, reduce GHG emissions and increase carbon sequestration. They strengthen food security and deliver both financial and environmental benefits. Practices that do not involve imported inputs or cash outlays and concerned with improving FYM quality offer a bottom-up, boot-strapping way to reverse the downward spiral of declining soil fertility. Socio-political commitment, and policy and programme initiatives are therefore required to directly support the smallholder farmers to adopt such agricultural options on a wider scale. If agriculture is to be part of the solution to climate change, and at the same time, continue to contribute

to food security and poverty alleviation, there will be a need for a significant increase in investment in climate-smart agricultural policies and practices. Since failure in making this shift would put future food security at risk, greater emphasis needs to be placed on agriculture in climate change policy discussions. This will ensure that agriculture fully contributes to future adaptation and mitigation efforts without undermining food production and the fight against poverty.

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