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Evaluation of Conservation Tillage Techniques for Maize Production in the Central Rift Valley of Ethiopia

Bisrat Getnet[1], Laike Kebede[1] and Hae Koo Kim[2]

[1] *Department of Agricultural Mechanization Research, Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center, P.O. Box 436, Adama, Ethiopia*

[2] *International Maize and Wheat Improvement Center (CIMMYT), P.O. Box 5689, Addis Ababa, Ethiopia*

አሕፅሮተ-ጥናት

የዕቀባ እርሻ የአፈር መሸርሸርና መከላትን እንዲሁም የመሬትን ለምነት የሚጨምር የአስተራረስ ዘዴ ነው። ከእቀባ እርሻ ዓይነቶች መካከልም የእርሻ ድግግሞሽን በመቀነስ ለችግሮች ዋነኛ መፍትሔ ነው። በዚህ ሙከራ አምስት ዓይነት የአስተራረስና የአዘራር ዘዴዎች ፍተሻ ተከናውነዋል። እነርሱም፡ መስመር ተከትሎ በተሻሻለ ማረሻ አንድ ጊዜ በማረስና በእጅ በመዝራት፣ በእርፍና ሞፈር ላይ በሚገጠም ገልባጭ ማረሻ ሁለት ጊዜ ሙሉ እርሻ ማከናወንና በመስመር በእጅ መዝራት፣ መስመር ተከትሎ በባህላዊ ማረሻ አንድ ጊዜ በማረስና በተመሳሳይ ጊዜ ማረሻ ላይ በተገጠመ መዝሪያ መዝራት፣ መስመር በመከተል ዘር በሚዘራበት ቦታ ላይ በመቆፈሪያ በትንሹ በመቆፈር በእጅ መዝራት፣ ምንም ሳይታረስ ጃብ ፕላንተር በተባለ መዝሪያ በመስመር መዝራት ናቸው። የዕቀባ እርሻ ዘዴዎችን ለመገምገምና ያላቸውን ተፅዕኖ በእርሻ ጊዜ እንዲሁም ለእርሻ የሚያስፈልግ የሰው ሃይልና ለመዝራት የሚወስደውን ጊዜ፣ ከብቅለት በፊትና በኋላ ያሉ ተጓዳኝ መረጃዎች፣ እንዲሁም በአፈር ኬሚካል ይዘቶችና የምርትና ተረፈ ምርት ሁኔታ ጋር ያለውን ዝምድና በመልካሳ ሁለት በቆሎ ዝርያ በመጠቀም ሙከራው ተከናውኗል። ሙከራው በመልካሳ ግብርና ምርምር ማዕከል በ2004 ና በ2005 ዓም. መኸር ወቅቶች ተከናውኗል። የንፅፅር ውጤቶችም እንዳመለከቱት ምንም ዓይነት የአፈር ኬሚካል ይዘት ለውጥ በሁለት ዓመት ውስጥ አለመታየቱንና እንዲሁም መስመር ተከትሎ በማረሻ አንድ ጊዜ በማረስና በእጅ በመዝራት በንፅፅር ከተሞከሩት የአስተራረስ ዘዴዎች አነስተኛ የእርሻ ጊዜ ስለወሰደ የተሻለ ሆኖ ተገኝቷል፣ ለማረምም የሚወስደው ጊዜ ከእርፍና ሞፈር ላይ በሚገጠም ገልባጭ ማረሻ ሁለት ጊዜ ሙሉ እርሻ ከማከናወን በስተቀር አነስተኛ መሆኑ ታይቷል። ምርትና ተረፈ-ምርት ላይ የተወሰዱ መረጃዎች እንደሚያመለክቱት መስመር ተከትሎ በተሻሻለ ማረሻ አንድ ጊዜ በማረስና በእጅ በመዝራት ምንም እንኳን የጎላ ልዩነት ባያሳይም የተሻለ ምርት አሳይቷል። በመሆኑም የዚህ ሙከራ ማጠቃለያ የሚሆነው የተዛባና ያልተስተካከለ ዝናብ ባለበት ሁኔት ከእቀባ እርሻ ዘዴዎች መካከል መስመር ተከትሎ በተሻሻለ ማረሻ አንድ ጊዜ በማረስና በእጅ በመዝራት የተሻለ ውጤት ያሳየ በመሆኑ የእርሻ ድግግሞሽ እንደማያስፈልግና የእርሻ ጊዜን እንደሚቆጥብ፣ የዘር ጊዜን በወቅቱ ማከናወን እንደሚያስችል፣ የሰውና የእንሰሳ ምልልስና ድካምን እንደሚቀንስ ለማወቅ ተችሏል። በመሆኑም በወቅቱ ለመዝራት እንዲቻልና የተፈለገውን ዘር በአግባቡ በተፈለገው ቦታ ለማከናወን በተሻሻለው የእርሻ መሳሪያ ላይ የሚገጠም የዘር መዝሪያ ቢኖር በዚህ ሙከራ ከተገኘው ውጤት የተሻለ ውጤት ማግኘት እንደሚቻል ይህ ጽሑፍ ምልከታውን ያቀርባል።

Abstract

Conservation tillage as an approach to reduce surface runoff and soil degradation and reduced tillage systems may offer a compromise solution. The objective of the study is to test different conservation tillage techniques and evaluate the impacts of the system on conserving water, labor requirement for pre and post planting, soil physicochemical properties, plant growth and yield. The experiment was conducted in a semi-arid area in the central Rift Valley of Ethiopia during 2012 and 2013 cropping seasons. The different planting methods used as treatments were: ripping with manual planting, conventional tillage involving two passes with animal drawn moldboard plow, ripping once with ripping attached row planter, pitting and no-tillage with hand pushed jab planter were evaluated using Melkassa II maize variety. Results have been compared with conventional tillage involving two passes with animal drawn moldboard plow. Soil chemical properties monitored before and after tillage to a depth of 15cm though were not statistically significant. The study showed that the performance of ripping followed by manual *planting tillage system was superior to the other four tillage treatments in tillage time, and weeding time, except the conventional tillage system. Ripping once and planting is a better in saving tillage time, avoiding delayed planting and drudgery to animals and human beings compared to reduced tillage system in areas where the rainfall pattern is erratic in nature as rift valley. It is also recommended that the right time of planting with uniform seed placement can be achieved if there is an efficient row planter that can be attached to the ripper.*

Introduction

Ethiopian farmers have been practicing excessive soil tillage using animal traction for thousands of years (Goe, 1987) with the purpose to favorable environment to plant growth (Klute, 1982), to control weeds, conserve moisture, and increase soil warming (Temesgen, *et al.,* 2008). The tillage frequency for maize production in the low rainfall areas is up to four passes (Temesgen et al., 2008). Tillage is physical, chemical or biological soil manipulation to optimize conditions for seed germination, emergence and seedling establishment Lal (1976). However, this approach with little or no ground cover poor land management enhances soil erosion and land degradation (Zeleke, et al., 2006). Tillage in moisture stressed areas also causes delayed planting and inefficient use of soil and water resources resulting in low crop yield (Temesgen, 2007). Repeated tillage also induces high drudgery to both draft animals and human beings and consumes the large proportion of the total energy expenditure in all agricultural field operations (Temesgen, 2007; Pathak, 1987).

Conservation tillage (CA) is prescribed to protect land degradation and reclaim degraded lands. The objectives of CA are to achieve soil, water and energy conservation by providing optimum seedbed rather than homogenizing the entire soil surface. leaving 30 percent or more of the crop residue on the soil surface. This keeps field compaction to a minimum, reduce energy input and labor requirement (Subbulakshmi, et al., 2009). It also ensures more moisture storage, reduces surface runoff, benefits the crop in arid and semi-arid areas by reducing drought risk and increasing grain yield (Rockstrom et al., 2001; Temesgen, et al., 2000, 2001) than conventional tillage. CA relieves labor bottlenecks, animal and mechanized draft requirements out of the peak planting period.

Under conservation farming, land preparation takes considerably less time, thus farmers sow in the first rains when plants will benefit from initial nitrogen flush in the soil.

Previous studies have reported the impacts of CA on yield, soil and water productivity and management of weeds and pests (Schlesinger, 2001). Different CA systems, such as contour ploughing, ripping, potholing and zero tillage have been developed with the aim of reducing run-off and sheet erosion (Nyagumbo, 2002). However, little attention was given to methods and techniques appropriate for a specific agro-ecology. Neither technologies and alternative techniques, nor information which can be utilized as integral part of conservation tillage is available to semi-arid environments in Ethiopia.

The study reports an estimate of pre- and post-planting labor and time required as well as agronomic benefits for four different conservation tillage techniques compared to the conventional tillage system.

Material and Methods

The study area

The experiment was conducted in Ethiopian Institute of Agricultural Research, at Melkassa Research Center. The soil type is predominantly sandy loam. The daily maximum temperature becomes very high during the months of March to June, during which the temperature can reach as high as 34.5°C. The mean annual temperature is about 28.5 °C. Mean annual minimum temperature is 14.5 °C. Melkassa has a highly variable annual rainfall that ranges between 500 and 800 mm.

Treatments

Five treatments were laid out in randomized complete block design with three replications. Fertilizer was applied at a rate of 100 kg ha^{-1} DAP (23 kg N_2 and 46 kg P_2O_5) during planting and 50 kg ha^{-1} Urea 35 days after planting. Single plots with 10mx40 m size were used. The following were the different treatments.

1. Conventional tillage (CP) in which the land was plowed twice, according to the farmers practice using oxen drawn moldboard plough prior to planting on the same day of planting. Seeds were row planted manually at 75cm row spacing and 25 cm between plants.
2. Ripping and manual row planting (RIP+MP) in which the planting lines are opened at 75 cm spacing with modified *Maresha* before planting on the sowing date. Plots are cleared of weed with cutlass before planting. Seeds were row planted manually at 75cm row spacing and 25 cm between plants.
3. Ripping and planting with row planting equipment (RIR+RP) in which plots were ripped as described in treatment 2 above, but planting is done with an animal drawn row planter attached to the ripper simultaneously.
4. Pot holing /pitting (PIT) were made by digging holes at a depth of 5cm and putting seeds directly in half soil filled holes and covering the seeds with soil.
5. Hand pushed Jab planter (JP) in which a hand pushed jab planter was used to plant seeds in a row at 75cm row spacing and 25 cm between plants.

Crop varieties and management

Melkassa-II maize variety, an intermediate maturity maize variety and potential grain yielder (5-6 ton ha^{-1}) in low moisture areas, was used for the experiment. The row spacing was 75 cm. Sowing was done at 1 to 2 seeds per hole and desired plant stands were obtained by thinning the stand when the crop was at 3-4 leaves stage. Shallow weeding was done manually for all plots before planting. Major weeding without disturbing the soil was conducted twice until harvesting each time weeds reached more than 10 cm in height using hand weeding.

Data collection and analysis

Pre-planting soil samples were collected at three points along the diagonal of each plot at 0 to 15 cm depth for analysis of pH, bulk density, soil texture, soil organic carbon and total N. The analyses were conducted according to the procedures summarized by Van Reeuwijk (1993). Plant stand counts were recorded before thinning (3 weeks after planting) and at harvesting by counting the actual number of plants at two spots on 4 rows of 5 m length in each plot and expressed on hectare basis. Five random plants in the central four rows were selected for each treatment to measure plant height at physiological maturity. Leaf area and dry matter accumulation of sample plants were taken by cutting the whole plant above the ground level and fractioned into leaf, stem, tassel and head) Leaf area was measured at flowering and maturity by sampling three random plants per treatment. Finally, leaf area index (LAI) was calculated by dividing the total area of green leaves in the samples by the ground area sampled. Immediately after leaf area measurement, sample plant components were dried in an oven at 70 °C up to constant weight.

Weed infestation was evaluated once a year. Weed counting was conducted before hand weeding, using the weight–counting method on the quadrant of 1 m^2 area in each replication. One quadrant was established for each replication (10 m by 40 m) in the middle parallel rows to cover rows. A destructive sample was taken in the quadrants and the weeds were identified and grouped into broadleaves, perennials and annual grasses. These groups were counted separately and were oven dried at 70°C for 48 hours then weighed.

To describe species diversity, we used Margalef`s index–DMG as a measure of species richness, calculated according to the following formula:

$$D_{MG} = (S - 1)x \log N^{-1}$$

where S denotes the number of species and logN is the logarithm of average total weed density (plants m^2) in each plot (Magurran, 1988).
The number of human labor and animals involved and time taken (person hours) to complete the activity on each plot for each operation (tillage, fertilizer application, seeding, seed covering, weeding etc.) were recorded.

The crop was harvested leaving out 1 m from each end and one row from each side of the plot. The total weight of above ground biomass was measured using a stationary balance of 20 kg capacity in the field. The cobs were carefully removed and shelled by hand and weighed. Moisture content of the grain was determined by drying in an oven at 70 °C for 24 h and grain yields were adjusted to 12.5% moisture content.
Data on labor time for different field operations, weed density, weed diversity, plant growth parameters, yield and yield components were subjected to statistical analysis of variance using Statistix 8. Least significant difference test of significance was used to evaluate differences between treatments (Gomez and Gomez, 1984).

Results and Discussion

Labor use in tillage techniques

Figure 1 shows labour requirment of major field operations for maize cultivation in four conservation tillage techniques and the corrosponding traditional tillage system. The results indicated that pitting/pot holing practice followed by conventional tillage consumed the highest labor time for tillage plus planting operations compared to other tillage practices (Figure 1 and 2). Ripping followed by jab planter on the other hand utilized significantly ($p<0.05$) lower labor time for planting and prior field operations.

Weed management under conservation tillage is more labor intensive than conventional tillage. More labor time was utilized for hand weeding of no till (Jab planter and pitting) plots compared to ripped fields. In all techniques, the bigest share of labor time was spent on weeding (Figure 2). Overall, conventional tillage consumed the mimimum total labor time for the whole field operations therefore, no labor saving benefit was observed for the complete farming resulting from CA techinque. With the exception of pitting, considerably less time were recorded for land preparation. Except for a ripper with manually operated row planting attachment, no significant differeces were observed between the rest of the treatments at planting. Among conservation tillage techniques, ripping is supperior labor use than the rest CA techniques.

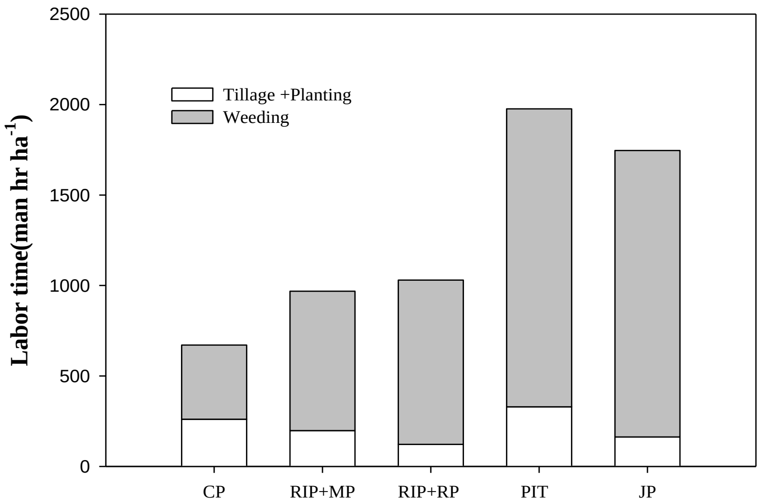

Figure 1. Effect of tillage techniques on labor use for major field operation

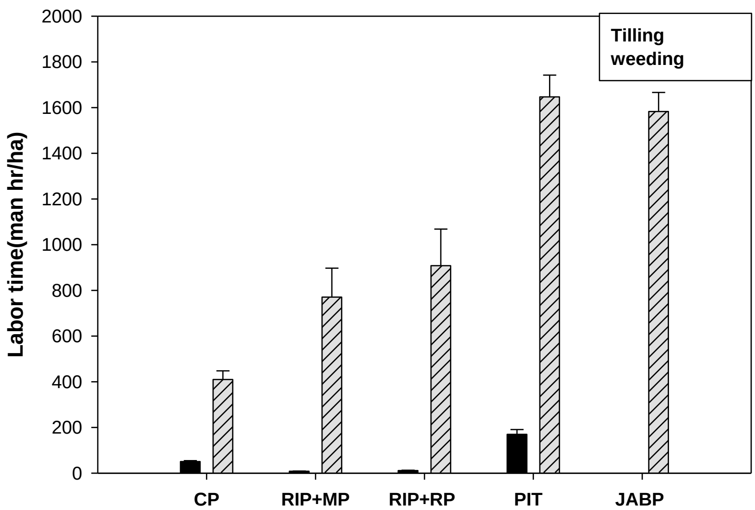

Figure.2 Labor time for tilling and weeding for tillage techniques.

The time taken by the ripping followed by ripper attached planter would have been more preferred if the attached row planter had functioned efficiently. This is because of the advantage of having two operations at the same time. Therefore, it is recommended that the available ripper attached row planter needs further improvement especially on the metering mechanism for seed, fertilizer as well as the handle at which it is operated so that one can improve row planter's ability to deliver seeds uniformly resulting in no unplanted gaps.

Zero tillage using hand pushed jab planter is not recommended for non-fragile soil which is easily penetrated by the planter tip. Enormous labor is also saved by using hand-pushed jab planter. One person is able to plant a quarter of a hectare in 12 hours where as under conventional tillage it would take 19 hrs to plant manually the same plot size in addition to plowing. Furthermore, compactness of the device makes it suitable for operating on hilly, stony, stumpy areas and for intercropping. Therefore, jab planter saves tillage time for those farmers who have no oxen at all and for soils that are naturally fragile. Despite some skills needed, it is an ideal tillage option for its compactness and accessible to small holder farmers.

Pitting tillage option would have been the best option if tillage time would not have been highest, considering the long-term effect of conservation tillage when compared with the conventional tillage. Unless otherwise, the labor time for tillage is lower than weeding labor time, it is not be recommended to use pitting tillage technique.

Soil properties and tillage depth

Table 1 shows physical and chemical properties of soils at the trial site. Changes in soil chemical properties such as organic matter content, percent nitrogen, and soil pH were found statistically insignificant before and after tillage for all treatments. The SOC and TN contents of soils take longer (>5 years) to respond to reduced tillage (Heenan *et al.,* 2004) while others reported significant changes in shorter periods of two to three years (Ozpinar and Cay, 2006; Temesgen Melese, 2007).

Table1. Physical and chemical properties of soils at the trial site before and after planting

Parameters	Mean values
Soil texture (%)	
Sand	62.10 ± 2.12
Silt	25.30 ± 1.08
Clay	12.60 ± 1.26
Bulk density(gm cm^{-3})	1.57 ± 0.28
Moisture Content (%) (wet basis)	20.46 ± 4.30
Organic Carbon (%)	3.80 ± 0.29
Total Nitrogen (%)	0.71 ± 0.07
pH	7.29 ± 0.26

Table 2. Tillage/planting depth on the date of planting

Tillage systems	*Depth of operation(cm)
PIT	5.7±0.2
JABP	2.3±0.0
RIP+RP	12.7 ±0.3
RIP+MP	12.7 ±0.4
CP	14.9±0.5

Effects of tillage methods on plant growth parameters

Significant difference ($p<0.05$) occurred in seedling emergence for tillage types (Figure.6a). Stand count (plants ha^{-1}) at emergence were 66370, 60148, 58074, 50963 and 47630 respectively for conventional tillage,ripping involving manual planting, pitting, ripping with manually operated row planting attachment and hand pushed jab planter treatments. There is no significant difference on plant height for all treatments. However, in 2013 cropping season, plant emergence count (plants ha^{-1}) was significantly higher for pitting (57295), ripping followed by manual planting (53527) and jab planting (53043) treatments respectively than conventional mold board plowing (37681) and ripping attached row planting (19614) treatments (Figure 3).The main reason for the lower stand count for conventional mold board plowing was due to erosion at the time of emergence whereas the ripper attached row planter often misses and makes large unplanted gaps between plants.

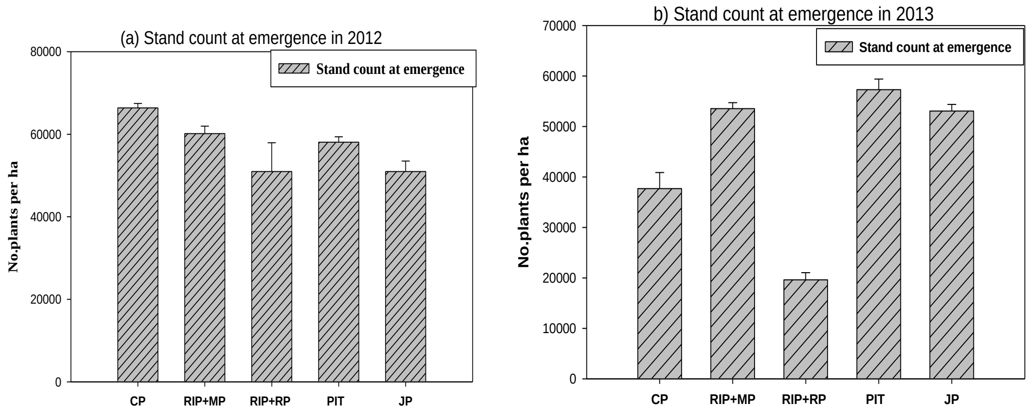

Figure 3. Stand count at emergence for different tillage techniques in 2012 and 2013.

Tillage methods had no significant effect on leaf area index (LAI) prior to flowering in 2012 cropping season. However, ripping and manual planting resulted significantly in the highest LAI at late reproductive stage, followed by conventional tillage. Generally, the lowest growth was found in no-tillage treatments (Figure 4).This could be due to a very shallow tillage which will impede root development and moisture infiltration near the plant root.

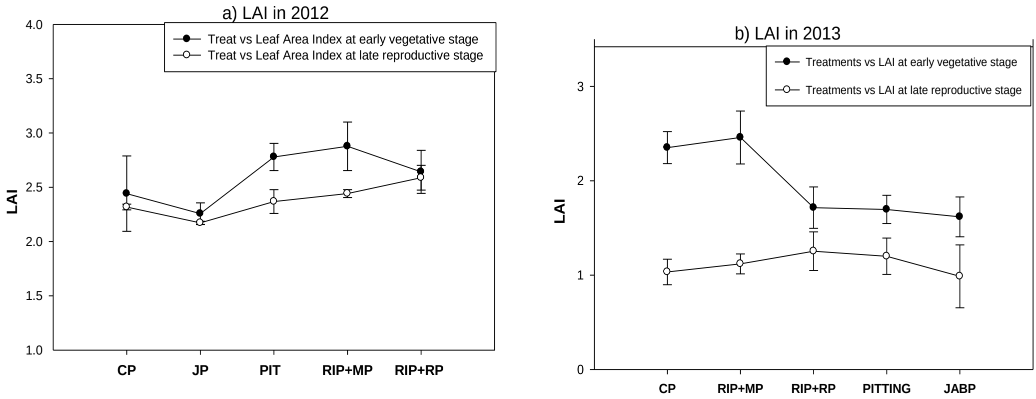

Figure. 4. Effect of tillage type on LAI in 2012 at vegetative stage and at late reproductive stage (a) and LAI in 2013 at early vegetative stage and late reproductive stage (b)

Effect of tillage on weed density and weed composition

Total weed count was significantly higher ($p<0.05$) under conservation tillage treatments than other treatments (Table 3)., the total weed counts were 13 times in zero tillage involving pitting and hand pushed jab planting, and 6 times with ripping (minimum tillage) techniques compared to the conventional tillage practice. A total of 24 weed species were identified and counted from sampled areas of experimental plots. Dominant weeds were *Desmodium sp.*,C*cyperus sp., Parthenium sp. and Argemoneoc hroleuca sp.;* each ranged from 14.3-23.25% of the total density. A lower density of perennial weeds, 2.6 plants m^{-2} were observed in conventional tillage plots as compared to conservation tillage treatments that ranged from 7.5–9.0 plants m^{-2}. The effectiveness of conventional tillage for weed control is attributed to the higher degree of soil disturbance by ploughing the entire field and burring the weeds.

Table 3.Weed density and diversity in 2012 and 2013

Tillage systems	Weed density(No.m^{-2})		Weed diversity index	
	2012	2013	2012	2013
CP	18.83 ± 8.50c	77.67±15.88c	2.17 ± 0.35a	2.24±0.99a
PIT	245.33 ± 14.36a	210.58±50.38ab	2.36 ± 0.18a	2.80±0.40 a
JP	225.17 ± 65.64a	288.08±39.90a	1.84 ± 0.24a	1.88±0.52 a
RIP+MP	112.00 ± 39.3bc	158.50± 12.52bc	2.03 ± 0.38a	2.74± 0.93a
RIP+RP	117.00 ± 38.61b	224.92± 36.49ab	2.06 ± 0.28a	2.13±0.23 a
LSD	94.19	87.49	0.908	2.34
CV	34.82	24.21	23.04	52.71

*Means within the column followed by the same letters are significantly different at ($p<0.05$),
Mean ± SE; SE = standard error

Effect of tillage on grain yield and biomass

The study showed significant ($p<0.05$) difference in maize grain and biomass yield among tillage techniques in 2012 and 2013 cropping seasons (Tables 4). The highest grain and biomass yields were obtained from ripping involving manual planting. In contrast, ripping with a row planter attachment resulted in lower yield than the rest of the tillage techniques. This was attributed to the clear difference in planting methods where seed spacing was not uniform in a row planter attached to a ripper. In general, no significant yield benefits were obtained from the other tillage techniques compared to the conventional tillage system during 2012. However, significant yield difference was observed ($p<0.05$) in 2013 cropping season. Although yield was observed to be lower for all treatments as compared to the previous year due to low amount of total seasonal rainfall, the highest grain yield was obtained from ripping followed by manual planting treatment. This was a clear indication of better moisture availability to the root zone even when there is a dry spell during the cropping season.

Table. 4: Effect of tillage methods on yield and biomass in 2012 and 2013

Tillage systems	Grain yield (kg ha^{-1})		Biomass (kg ha^{-1})	
	2012	2013	2012	2013
CP	3019.0±571.52ab	1398.84±40.89b	10222 ±1428.71ab	4565.58±195.64bc
PIT	2806.2±419.73ab	1445.52±113.19b	9556 ±2041.05ab	5171.46±466.62ab
JP	2609.3± 18.19b	1273.36± 58.07b	9111 ±128.29b	4119.1626±10.72c
RIP+MP	3617.8±81.18a*	1868.21±107.17a*	12237 ± 237.06a	6118.36± 133.97a
RIP+RP	2546.0± 34.01b	836.36± 218.67c	8356±92.55b	2329.70±483.14
LSD	962.09	420.79	3108.1	1029.0
CV	17.5	16.38	16.68	12.25

*Means within each column followed by the same letters are not significantly different at ($p<0.05$), mean ± SE;

Financial analysis

The financial analysis results (Tables 5 and 6) indicated that ripping tillage followed by manual planting had the highest net benefit than the rest of treatments under study. The costs of operation were calculated based on labor hiring rates for tillage operation was 30 Birr-day^{-1} (1 USD=18.87 Birr). Weeding operation labor cost was 40 Birr-day^{-1} and Financial analyses were made by using the sum of costs of implement use, tillage, planting and weeding operations as total expense and sales from maize grain at 6 Birr-kg^{-1}. The costs of implement use were calculated based on the current prices of the implements that are on sale while estimates were given to those not yet in the market (Table 5).

Table 5. Cost of implements use

Operation	Price(Birr)	Service life(hrs)	Unit time (hr.ha^{-1}-operation)	Cost (Birr-ha^{-1}-operation^{-1})
CP*	450.00	200	51	114.75
RIP	320.00	200	8.41	13.46
RIP+RP	870.00	200	11.31	49.20
PIT	50.00	200	170	42.50
JABP	892.00	200	51.21	228.39

The net result of the financial analysis was in favor of the ripping tillage system followed by manual planting this is due to the higher grain yield than the rest of the treatments and relatively lower weeding cost as compared to the reduced tillage treatments.

Table 6. Financial analysis at Melkassa (mean values)

Treatments	Cost:Birr-ha^{-1}				Total cost	Revenue	Net benefit
	Tillage	Weeding*	Planting	Implement	Birr ha^{-1}	(Birr-ha^{-1})	(Birr-ha^{-1})
CP	1800.00	2050	270	114.75	4234.75	18114	13879.25
RIP+MP	310.00	3855	270	13.46	4448.46	21706.8	17258.34
RIP+RP	417.00	4540	0	49.20	5006.20	15276	10269.8
PIT	638.00	7915	176	42.50	8771.5	16837.2	8065.7
JABP	0	8235	192	228.39	8655.39	15655.8	7000.41

*Weeding operation was conducted twice for the cropping season.

The findings of this study showed that in terms of tillage along with planting operations rip tillage reduced labor usage. Pitting on the other hand is laborious, time-consuming and associated with drudgery. Weed problem was the serious issue observed in the four conservation tillage methods evaluated.When reduced and zero tillage were employed 2 and 4 times higher labor were utilized for weeding, respectively compared to CP plots. Overall, weeding in CA accounted 80 to 90 % labor uses with a maximum for zero tillage systems involving pitting and jab planter. Previous studies also reported higher weed pressure in the use of conservation tillage systems (Baudron et.al, 2011; Giller et al, 2009).Although no labor saving benefits were observed from conservation tillage techniques, rip tillage systems utilized less labor for total field operation among the rest of the tillage methods.

On average 19.8% increased yield obtained from ripping + manual planting compared to CP could be attributed to more water retention of the soil as opening planting lines provide a better environment for root growth and improve infiltration of rainfall. A number of studies reported similar or better yield benefits under conservation tillage .The lowest grain and biomass yield obtained from the ripper attached with hand operated row planter was because of the planter's non-uniform seed dropping caused by the difficulty in maneuvering oxen during rip plant operation. The poor yield performance of hand pushed jab planter could be due to poor penetration of the unploughed compacted soil and placement of seeds at a shallow depth. Considering a relative better yield benefit, superior labor performance among the tillage methods and the presence of long tradition in animal traction in the country, ripping may have a good potential for adoption by farmers in the Ethiopian context. Furthermore reduction of soil erosion and degradation in the long-term are expected as main advantage of the technology. However, appropriate weed control options need to be packaged for the promotion and eventual adoption of conservation tillage systems.

The study showed reduced tillage systems like ripping tillage can produce slightly higher or similar yield and yield components to conventional tillage systems, while maintaining adequate residue cover and reducing the risk of soil erosion. Therefore it can be concluded that reduced tillage systems like ripping tillage can perform greatly, with minimal effect on crop yields and often at lower tillage time, than conventional tillage. Labor, plant growth and yield differences were observed among CA techniques with overall better performance for rip tillage + manual planting. Considering planting time window and unpredictability of rainfall onset in the Rift Valley areas, farmers will not spend time for primary and successive tillage operations; if they utilize rip tillage, which requires less plowing time.

The lower yield performance of hand-pushed jab planter is due to zero plowing and planting depth. This is the result of the soil type being not fragile enough to be penetrated easily to the minimum required planting depth. This could also mean that sandy loam soil under study has low drainage characteristics making it unsuitable for zero tillage without complete soil cover.

Increased weed intensity and weeding labor observed in CA techniques could negatively affect promotion and be the bases for eventual adoption of CA. Although labor time required for weeding is quite high, it can be solved by applying pre-planting herbicide. It can also be argued that the cost of labor for weeding operation per day is much lower than the cost of labor for tillage operation, making the rip planting tillage option acceptable to small holder farmers. In addition, ripping tillage needs only additional two iron rods; while using *Marehsa* plow without significant additional cost.

In dry seasons when there is high rainfall variability during seedling emergence soon after planting, there could be intensive runoff leading to lower stand count in conventional moldboard tillage than reduced or no tillage.

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