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Study and Analysis of Tillage Systems on Energy Consumption for Faba Bean Bean *(Vicia Faba L.)* Production

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Abstract
Unidentified types of tillage systems used for different tillage activities, expose workers to various unanticipated energy consumption and costs. This study aimed to determine the effect of conventional tillage (CT), minimum tillage (MT), and No-tillage (NT) systems on energy consumption for faba bean production. The field experiments were carried out for two years from 2021-2022 at Kulumsa Agricultural Research Center (KARC), and for data analysis, SPSS statistical software was used. The experimental field was designed by using the Randomized Complete Block Design method, with three treatments and three replications. The treatments consisted of Conventional Tillage (tillage with mouldboard plow and seed planting), Minimum Tillage (minimum soil disturbance with a cultivator and seed planting), and No-Tillage (direct seed planting).Input energy parameters; like Biological Energy (BE), Chemical Energy (ChE), and Field Operation Energy (FoE) were calculated for each tillage system. B.E had reported higher energy in MT (217.99 GJ/ha and FOE also had higher in CT (25.1(GJ/ha). Grain yield output in 2021 and 2022 was (409.9kg/ha) and (567.3kg/ha) respectively.The straw yield was 390.1kg/ha in 2021 and 506.8kg/ha in 2022, respectively. The results of Energy indices for CT, MT, and NT systems were obtained. In this regard, the CT system had a higher net energy gain (17823.28J/ha), Energy use efficiency (40.82), and Energy Profitability (39.04) respectively, than the NT systems. Minimum tillage also had a higher energy Productivity of 22.53MJ/ha than No tillage (21.69MJ/ha). Lastly, higher Specific energy was observed in NT (0.048) than in CT (0.045).
The lowest human labor of 90.92 hrs/ha, and field consumption of 31.03liters/ha, were observed for the no-tillage system. And highest grain yields of 5565.5 Kg/ha and Net energy gained of 17823.28 GJ/ha were noted for conventional tillage systems at KARC Kulumsa village, Ethiopia.
Keywords:Energy Consumption, RCBD, Tillage, Energy Indices.

1. Introduction

Tillage is one of the activities done in agricultural fields for seedbed preparation and better seed germination. Different tillage systems are utilized for different soil types to protect soil from different types of erosion. Although the Ethiopian economy is dominantly based on agriculture, the selection and identification of tillage system practices have not been developed. Most of the time, conventional tillage systems are used for soil tillage. Due to this, for different tillage activities in the field, the energy consumption for different tillage systems was not investigated and identified.The backbone of the Ethiopian economy is agriculture. Ethiopian farmers mainly use the traditional way of farming, which involves conventional tillage practices for seedbed preparation and is energy-intensive. The use of an inappropriate tillage practices will cause soil erosion and reduce productivity (Mihretie *et al.,* 2022). Research findings show conventional tillage practices consume more energy when compared with other conservation tillage practices, and agriculture's productivity and profitability are directly affected by the amount of energy utilized (Tabatabaeefar *et al.*, 2009). Different conventional tillage implements have long-term social, economic, and environmental impacts, as well as significant changes in infield efficiency, energy efficiency, and fuel consumption (Kumar *et al.*, 2013).Agricultural activities are dominated by tilling the soil. Tillage is the mechanical manipulation of the soil with tools and implements to improve seed germination conditions (Gondal, 2021; Singh *et al*., 2018). There are different kinds of tillage practices. These are Conventional tillage, Minimum tillage, Zero tillage or No-Tillage, etc. Conventional tillage is a type of tillage used for the opening and loosening of the soil. In a conventional tillage system, intensive tillage is carried out, and it causes a hard pan, poor infiltration, and susceptibility to runoff and erosion. It also demands capital, increases soil degradation, consumes more input energy, needs more human labor, etc. (Hasanuzzaman & Practices, 2019).On the other hand, different countries have been using modern agricultural practices; like minimum tillage, zero tillage (or no tillage), mulch tillage, etc.,to solve problems and challenges encountered by conventional tillage systems. Minimum tillage is a kind of minimum soil disturbance through reduced tillage operations. According to Tabatabaeefar *et al*. (2009), using minimum tillage will save costs by reducing tillage operations and working time, minimizing soil compaction, and reducing soil erosion and degradation. Similarly, zero tillage, or (No tillage, is advantageous for seed planting without disturbing soil and seedbed preparation by using the previous crop residues (Lv *et al.*, 2023). And it is also environmentally friendly among different tillage systems (Abolanle *et al.*, 2015, Kolhe 2009). Minimum and No-Tillage have their drawbacks in terms of soil compaction and weed infestation problems.In regions with a short growing season, the faba bean (Vicia faba L.) has the potential to be grown as a multipurpose crop. Due to its high nutritional value, medicinal significance, and efficient nitrogen fixation, it is grown throughout the world (Etemadi *et al*., 2019, Kolhe *etal*., 2010). It is also a major food that feeds legumes due to its high protein and starch content. It can be eaten fresh, frozen, canned, or dry. According to Mohar and Ishwari (2013), the main faba bean-producing countries are China, a few European countries, Ethiopia, Egypt, and Australia. According to CSA (2018), 3.45% (about 437,106.04 hectares) of the arable land was occupied by faba beans in Ethiopia.The grain yield obtained from faba bean was 3.01% (about 9,217,615.35 quintals). In Oromia regional state, the coverage of faba beans is very high, when compared with other regional states in Ethiopia. The area of coverage in hectares is 204,387.86, production in quintals is 4,832,016.57, and yield (Qt/Ha) is 23.64. The faba bean is abundantly produced at an altitude between 1800 m and 3000 m. It is planted in warm soils (min. temperature preferably above 13-degree Cent). Sandy loam, sandy clay loam, or clay loam with a clay content between 15 and 35% is suitable. The mean temperature requirements are min. 10-degree centigrade and 27-degree centigrade, respectively (Amare Tadesse, 2018, Kolhe 2015). The main objective of this research was to investigate the effect of different tillage systems on faba bean production at Kulumsa Agricultural Research Center.

2. Material andMethods

2.1 Materials

The materials utilized for this study includeImplements (mouldboard plow, cultivator, seed planter), tractor, stake, sickle, sack, measuring devices, fuel measuring device, balance, seed, chemical sprayer, hammer, soil sampler, and fertilizer.

2.2 Experimental Methods

The experiments were carried out at Kulumsa Agricultural Research Center located in Oromia regional state Arsi zone, located at 167 km distance from Addis Ababa and 67 km from Adama town. Kulumsa is located at latitude/longitude 8º2' N and 39º10'E and an Altitude of 2200 meters above sea level, it has 10ºC and 22 ºC min/max temperature and mean annual rainfall is 788 ml. ItsAgroecological zone is from cool highland to semi-arid and dominated by clay soil.

The experimental details are presented in Figure 1 below. The experimental methodology for energy consumption of fababean production at KARC Kulumsa Village;

- Identifying and decidingthe amount of labor and time required for each activity in the experimental field(Tillage, cultivator, fertilizer application, seed planting, weeding, and harvesting) as shown in figure (a-f.)
- Measurement of diesel fuel consumption for different activities(tillage, cultivation, seed planting) by using standard methods.
- The weight of grain and straw yield from each plotwere measured by using weighing balance as shown in Fig. 1 (h-i)

2.3 Design of Field Experiments

A completely randomized block design (CRBD)of three different tillage treatments with three replications was used as shown in Figure 2. To carry out a field experiment 50x50M^2

area of land experimental site position was used. The area of land was divided into three blocks and nine plots, 15x20 M^2.

The treatments were designed based on the following three tillage systems.

i. Conventional Tillage(CT)**:** Tillage (*Lemken Europal 5* (Mould board plow) + (Planting (Lemken Saphir 7 (Seed Drilling Machine)

ii. Minimum Tillage(MT)**:** Lemken Kristall 9 Cultivator + Planting (using Lemken Saphir 7 Seed Drilling Machine)

iii. No-Tillage(NT): Only Planting using Lemken Saphir 7 Seed Drilling Machine)

A calculation and analysis were done on the amount of energy used in the summer of 2021 and 2022 to produce faba beans. The time needed for human labor to complete various tasks, such as tillage, fertilizer application, weeding, pesticide application, and harvesting. Also; fuel consumed during (tillage, transportation, and seed planting); the time required for field operation (transportation, seed planting, and tillage); and the amount of fertilizers, pesticides, and seed, were carefully recorded to determine the input energy consumed during different tillage practices. The grain yield and straw yield were also used to calculate the tillage systems' output energy. The standard formula was used to calculate energy indices; like Net energy gain, Energy use efficiency, Specific energy, Energy productivity, and Energy profitability. After determining the input-output energy parameters for each plot's treatments, data analysis and graphing were done using SPSS and MS Excel.

2.4.Determination of Energy

The energy inputs; are calculated by summation of biological Energy, Chemical energy, and field operational energy for the various tillage systems by using equation (1) as stated by (Nasseri, 2019)

$$Ei = BE + ChE + FOE \quad [1]$$

Where; Ei:InputEnergy, BE: Biological Energy, ChE: Chemical Energy, FOE: Field Operation Energy

The Biological Energy is calculated by using equation (2) (Ali et al., 2013)

BE = labor x EE, EE is equivalent to Energy [2]

The Chemical Energy is calculated by using eq (3) stated by (Tabatabaeefar*et al.*, 2009) and (Kheiry & Dahab, 2016)

ChE = FE + PE [3]

Where FE is fertilizer energy,PE is pesticide energy. However; FE and PE are calculated by using equations (4) and (5).

$$FE = WF(N)X[EM(N)XE(N)] + WF(P)*[EM(P)XE(P)] \quad [4]$$

Where; WF(N):- Allowed amount of fertilizer, EM(N) :- pure fertilizer , EN (N):- energy to produce pure fertilizer, WF(P) :- recommended dose of phosphor, EM(P):- pure phosphor *per cent and* E(P) :-energy required to produce pure fertilizer

PE = Pes X Peq [5]

PE- Pesticide Energy,

Field Operation Energy is specified as transportation, tillage, seed planting, plant protection, and harvesting is calculated by using equation (6) stated by (Tabatabaeefar*et al.*, 2009)(Kheiry & Dahab, 2016)

FOE = Human labor + Mechanical Power [6]

The Labor Energy Input and Mechanical Energy Input are calculated by using eq. (7) and (8).

$$\sum_{l=1}^{l=s}\left[\frac{(0.268\mathrm{L_f}.\mathrm{wd}_{\mathrm{lf}}\,\mathrm{wh}_{\mathrm{lf}})+(0.268\mathrm{L_h}.\mathrm{wd}_{\mathrm{lh}}\,\mathrm{wl}_{\mathrm{lh}})}{\mathrm{Ap}}\right] \quad [7]$$

Where; Lfand L_h – number of family labor and hired labor

Wd_{lf} and wd_{lh} – number of working days for family and hired labor (day)

Wh_{lf} and wh_{lh} – number of working hours for family labor and hired labor (h/day)

Ap – planted area

Mechanical Energy Input

$$\sum_{l=1}^{l=s}\left[\frac{(MF_f N_{mf}.wd_{mf}.wh_{mf} F_{eq})+(MF_h N_{mh}.wd_{mh}.wh_{mh} F_{eq})}{Ap}\right] \quad [8]$$

Where; $\mathrm{MF_f}$and $\mathrm{MF_h}$ – Fuel consumption of power source machine $\left(\frac{\mathrm{L}}{\mathrm{h}}\right)$ for owned and hired a machine,

$\mathrm{N_{mf}}$ and $\mathrm{N_{mh}}$ – No. of owned and hired farm machine

$\mathrm{wd_{mf}}$ and . $\mathrm{wd_{mh}}$ – working day of owned and hired farm machine (day)

wh_{mf} and wh_{mh} − working hours for owned and hired machines (h/day)

F_{eq}

$$MP = \sum_{l=1}^{l=s} \left[\frac{(MF_h N_{mh}.wd_{mh}.wh_{mh} F_{eq})}{Ap}\right] \quad [9]$$

2.4 Determination of output energy: The output energy of foba bean production is determined by using equation (9).

$$Eo = EMP + EBP \quad [10]$$

Where EMP – Energy of the main product

$$\text{Eo} = \text{grain yield}\frac{\text{kg}}{\text{ha}} * \text{EE, energy equivalent} - 20\frac{\text{MJ}}{\text{kg}} \text{ for faba bean}$$

EBP – Energy of by-product

$$\text{Eo} = \text{straw yield}\frac{\text{kg}}{\text{ha}} * \text{EE, energy equiv} - 17.65\frac{\text{MJ}}{\text{kg}} \text{ for faba bean}$$

2.5 Determination of Energy Indices

Energy indices parameters Net energy gain, energy use efficiency, specific energy, energy productivity, and energy profitability were calculated based on input/output energy results(Nasseri, 2019)

i. **Net Energy Gained (NEG)** is the difference between output energy and input energy(Barut et al., 2011)

$$NEG = Eo - Ei(\frac{MJ}{ha}) \quad [10]$$

ii. **Energy Use Efficiency (EUE)** is total output energy divided by total input energy (Awadalla, 2021)

$$EUE = \frac{Eo\frac{GJ}{ha}}{Ei\frac{GJ}{ha}} \quad [11]$$

iii. **Specific Energy (SE)** is energy input divided by grain yield or energy input for producing 1kg of faba bean(Ghorbani et al., 2011)

$$SE = \frac{Ei\ (\frac{MJ}{ha})}{Gy\ (\frac{kg}{ha})} \quad [12]$$

iv. **Energy Productivity (EP)** is faba bean grain production by consuming 1 MJ of energy per a given hectare of land(Virk et al., 2020)

$$EP = \frac{Gy\frac{kg}{ha}}{Ei\frac{MJ}{ha}} \quad [13]$$

v. **Energy Profitability (EPF)** is calculated from net energy gained divided by total input energy (Barut et al., 2011)

$$EPF = \frac{NEG\frac{GJ}{ha}}{Ei\frac{MJ}{ha}} \quad [14]$$

For calculating the various energies as stated above; the input and output energy equivalents were taken from table 1 as presented below;

3. ResultsandDiscussion

3.1. Results

From this studies the following results are obtained as presented from table 2**-** 6. Similarly, field experimental results indicated on different tables were also shown from figure 3-16 to know the amount and level of differences observed among tillage systems.

3.2 Discussions

3.2.1 The Effect of Tillage Systems on Energy Input of faba bean production

The analysis of variance in Table 5revealed that there were significant differences among tillage systems. The No-tillage system required less human labor than the minimum tillage system. More diesel fuel was consumed also during conventional tillage systems and less during No-tillage. In the field operation activity, No-tillage consumed fewer hours than conventional tillage. Grain and Straw yield differences were observed among the three tillage practices in the production years of the two seasons.Human labor and seed were the variables required to calculate Biological Energy (see Table 2 and Fig: 4). Biological Energy is one of the input energies that determine how much input energy is consumed during different tillage practices. The experiment was carried out in this regard to determine the effect of various tillage practices, such as Conventional, Minimum, and No-tillage practices. The experimental results revealed that minimum amounts of Biological Energy in No-Tillage (204.9 GJ/ha) and maximum amounts of Biological Energy results were observed in Minimum Tillage (217.99 GJ/ha). Conventional

Tillage (214.26 GJ/ha) was the result observed between No-tillage and Minimum tillage practices. FOE showed that there was a significant difference between No-Tillage and the two treatments (CT and MT). The result showed that CT (25.1 GJ/ha) treatment had higher input energy than NT (18.1 GJ/ha) see table 2 and fig 5.

3.2.2 The effect of Tillage systems on the Energy output of faba bean production

The output energy result showed in Table 2, figure 6 and 7 that no significant differences observed among the tillage treatments. But, grain yield energy differences were observed amongtillage systems, CT (10018.67 kg), MT (9981.33 kg), and NT (9316.67 kg), respectively. Similarly, the straw yield also showed that CT (8252.76 kg), MT (8040 kg), and NT (7452.74 kg), respectively. The mean value of the conventional tillage system's grain yield (10018.67 kg) and straw yield (8252.76 kg) was greater than that of both the MT and NT tillage systems. The No-tillage system had lower grain (9316.67 kg) and straw (7452.74 kg) yields.Table 3 shows the amount of input and output energy equivalent for faba bean production. In the Ethiopian context, the energy consumption of faba bean production has not been studied so far. The results in the table showed the standardized input/output energy equivalent of faba bean production and a comparison of the obtained results from the two-year experiment in the field. As was observed from the table, fertilizer application and straw yield were not indicated due to a lack of standardized input/output and energy equivalents from different literature. Overall, the results obtained from the experimental field for faba bean production and energy consumption were within the standardized range.Table 5, Fig. 8, Fig. 9, Fig. 10, and Fig. 12 showed the effect of tillage systems on particular input and output energy parameters. In this regard, it was observed that different tillage systems had different input energies. In conventional tillage systems, diesel fuel (46.293±1.44 lit), field operation energy (7.78±0.2 hr), grain yield (500.9±80.6 kg), and straw yield (467.6±59.7 kg) were higher than the minimum and No-tillage systems. Human labor hour consumption was lower in No-tillage (90.9±40.3 hr) system than in the Minimum tillage

(111.22±11.97 hr) by 20.11%. Diesel fuel consumption was also lower in No-tillage (31.022±1.13 lit) system than in conventional tillage (46.293±1.44 lit) by 39.50%. Less field operation hours were also observed in No-tillage (6.58±0.11hr) system than in conventional tillage (7.78±0.2 hr), and it was by 16.71%. The time required to carry out field operations was higher in Conventional tillage by 16.71% than in the No-tillage system. Overall, using a No-tillage system requires less time to execute tillage activities than conventional tillage and Minimum tillage systems.The two years production yearstarting from June to September grain yields were 2021 (409.9±37.4 kg/ha) and 2022 (567.3±40 kg/ha), and the straw yields were 2021 (390.1 kg/ha) and 2022 (506.8 kg/ha), respectively (Table 4 and fig 3). The ANOVA result showed a significant production difference between the two consecutive seasons, with grain yield increasing by 32.21% and straw yield increasing by 26.02%.

3.1.1. Energy Indices

Net Energy Gain, Energy Use Efficiency, Specific Energy, Energy Productivity, and Energy Profitability in faba bean production were calculated and shown in table 6 and Fig. 13- Fig.17.

i. Net Energy Gained (NEG)

The net energy is the difference between the energy outputs to energy inputs. The analysis of variance in Table 6 and Fig. 13 showed that the Net Energy Gained in Conventional tillage (17823.28±2581.55 GJ/ha) was higher than No-tillage (16337.41±2993.94 GJ/ha). So Conventional tillage gained 8.70% more energy than No-tillage. It was reported by Alhajj Ali *et al.* (2018) in "Implications of No-tillage System in Faba Bean Production: Energy Analysis and Potential Agronomic Benefits" that No-tillage (143342.5 MJ/ha) had more net energy gain than conventional (146013 MJ/ha) and reduced tillage (136457.8 MJ/ha). It was also reported by Nasseri (2019) in "Energy Use and Economic Analysis for Wheat Production by Conservation Tillage Along with SprinklerIrrigation" that No-tillage (123.31GJ/ha) had higher Net energy than Conventional tillage (54.35 GJ/ha). On the other hand, the study showed that reduced tillage

(174836.58 MJ/ha) had a higher net energy gain than No-tillage (168747.375 MJ/ha) and conventional tillage systems (160091.675 MJ/ha). Overall, No-tillage gained more energy than conventional tillage and sometimes reduced tillage.

ii. Energy use efficiency

Table 6 and Fig. 14 revealed that less EUE was observed in the No-tillage (39.04±8.10) system than in Conventional Tillage (40.82±6.12), No-tillage system had 4.46% less EUE than Conventional Tillage. Even though the ANOVA table showed no significant difference was observed among tillage systems, Convectional tillage had relatively higher EUE than minimumtillage and No-tillage systems. But from different literature, the study results showed that due to the absence of some activities in No-tillage, the result was higher(Alhajj Ali et al., 2018).Research conducted on the" Effect of tillage systems on energy use efficiency in wheat-based cropping sequence" by (Taner et al., 2016) result also showed that No-tillage (3.19) system had higher energy than conventional tillage (1.87) and minimum tillage (2.43).

iii. ***Specific Energy***

It is defined as the energy required to till a specific area of land. Table 6 and Fig. 15 showed no significant difference among the tillage system treatments. Conventional tillage had 0.045, which was less than the No-tillage system's 0.048. According to this, the No-tillage system was 6.6% more efficient than the conventional tillage system. According to the study's findings, Barut *et al.* (2011) found that the No-tillage (0.54 MJ/kg) system was less energy-intensive than both the minimum (0.48 MJ/kg) and conventional tillage (0.49 MJ/kg) systems. On the other hand, the study result showed that conventional tillage (2.31 MJ/kg) had higher specific energy than reduced (1.99 MJ/kg) and zero tillage (1.91 MJ/kg) systems (Kumar et al., 2013).

Energy Productivity

The results of the ANOVA are shown in Table 6 and Fig. 16, where the No-Tillage system had a 21.69±21.70 Kg/MJ, the Minimum Tillage system had a 22.53±22.53 Kg/MJ Kg/MJ, and the

Conventional Tillage system had 22.39±22.40 Kg/MJ. This indicated that No-till systems had higher energy productivity than Minimum tillage systems by 0.62%. It was also confirmed by Barut *et al*. (2011) in their research results showed that minimum tillage had the highest energy productivity than both Conventional and No-tillage. It was also observed in the study results of the EUE of different tillage systems for wheat and chickpea production that the NT (86.73 kg/GJ) systems had higher energy productivity than reduced tillage (69.66 kg/GJ) and conventional tillage (51.16 kg/GJ)(Taner *et al*., 2016, Tefari and Kolhe 2021).

vi. Energy Profitability

The ratio of net energy gain to total energy input is known as energy profitability. The result of the ANOVATable 6 showed no significant difference among the treatments. The tillage system results were CT (39.82), MT (39.65), and NT (38.04), respectively. The energyprofitability of the conventional tillage system was 4.57% higher than that of the No-tillage system. The conventional tillage system had higher energy productivity than the No-tillage system by 4.57%.Taner & Zafer (2015) confirmed in their study results that NT (3.47) had higher energy profitability than RT (2.97) and CT (2.11).In their study, Alhajj Ali *et al.* (2018) also revealed that the NT (13.7) had higher energy productivity than the RT (9.3) and CT (9.6) as shown in Figure 17 below.

Conclusions

The following conclusions were drawn from the field experimental results:

- Comparisons of the input and output energy of different tillage systems showed that in minimum tillage systems, a higher input of biological energy was observed than No-tillage systems. Similarly; higher field operation energy was observed in conventional tillage systems than in minimum and No-tillage systems, respectively. In addition to this, a higher grain yield energy was observed in conventional tillage than in No-tillage systems. And, a higher straw yield was observed in conventional tillage than in No-tillage systems.

- The mean comparison of the two production years was increasing; in this regard, grain yield and straw yield in 2022 showed improvement, and it is promising to use different tillage systems for faba bean production.
- In the case of Energy indices differences among different tillage systems for faba bean production It is observed that Net energy gain (NEG), Energy use efficiency (EUE), and Energy profitability (EPF) were higher in Conventional tillage systems than No-tillage systems.No-tillage and minimum tillage systems had higher Specific energy (SE) and Energy Productivity (EP) than conventional tillage systems, respectively.

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List of Tables:

Table 1: Energy Equivalent of input and outputs for faba bean production

Inputs and Outputs	Unit	Energy Equi (MJ/unit)	References
A. Inputs			
1. Human labor	H	1.96	(Chaudhary et al., 2009);(Lal *et al*., 2019)
2. Machinery	H	62.7	(Lal et al., 2019);(Alhajj Ali et al., 2018)
3. Diesel Fuel	Lit	47.80	Shafique and Nasima (2018),
4. Chemical Fertilizer			
Nitrogen (N)	Kg	66.14	(Ali et al., 2018),(Kazemi et al., 2015a)
Phosphorus (P_2O_5)	Kg	12.44	(Kazemi et al., 2015a)
5. Pesticide	Lit	73.81	(Kazemi et al., 2015a)
6. Seed	Kg	21	(Kazemi et al., 2015a)
B. Outputs			
1. Faba bean grain yield	kg	20	(Alhajj Ali et al., 2018)
2. Faba bean straw yield	kg	17.65	(Alhajj Ali et al., 2018)

Table 2: ANOVA calculated results of Input/output Energy of different tillage systems

Energy(J)	Tillage Systems		
A. Input Energy	CT	MT	NT
BE(GJ/ha)	214.26±8.91A	217.99±23.47A	204.9±14.94A
ChE(GJ/ha)	208.79±0.00A	208.79±0.00A	208.79±0.00A
FOE(GJ/ha)	25.1±1.62A	19.58±0.8B	18.13±1.12B
B. Energy output			
EMP, Grain yield (Kg)	10018.67±1612.46A	9981.33±2132.11A	9316.67±1821.65A
EBP. Straw yield (Kg)	8252.76±1053.3A	8040.58±1462.30A	7452.57±1228.17A

EMP-Energy of the main product, EBP-Energy of the by-product

Table 3: Comparison of calculated input and output energy of faba bean production obtained from Experimental Field results at the Kulumsa Agricultural Research Center (KARC) with a review of the literature (Kazemi et al., 2015)

Inputs and outputs	Units	Energy input and output of Tillage Systems field experimental results			Total Energy Equivalent (MJ/ha) of tillage systems at KARC			Standard ranges of input and out energy and its energy equivalent for faba bean production					
A. Inputs		CT	MT	NT	CT	MT	NT	CT	MT	NT	CT	MT	NT
Human labor	Hr	109.3	111.21	90.92	214.23	217.97	178.19	61-322	61-322	61-322	119.56-631.12	119.56-631.12	119.56-631.12
Diesel fuel	Lit	46.3	41.67	31.03	2213.14	1991.83	1483.23	6.92-110	6.92-110	6.92-110	330.77-5236.00	330.77-5236.00	330.77-5236.00
Machinery	Hr	7.78	7.66	6.58	487.49	479.97	412.57	1–16	1–16	1–16	62.7-1000.3	62.7-1000.3	62.7-1000.3
Fertilizer	Kg	125	125	125	125	125	125	NA	NA	NA	NA	NA	NA
Pesticide	Lit	0.1	0.1	0.1	101.2	101.2	101.2	0.07-2	0.07-2	0.07-2	7.08-202	7.08-202	7.08-202
Seed	Kg	200	200	200	4200	4200	4200	20-200	20-200	20-200	420-4200	420-4200	420-4200
B.Outputs													
Grain Yield	Kg	5565.5	5544.95	5176.1	111310	110899	103522	2000-5670	2000-5670	2000-5670	40,000-113,400	40,000-113,400	40,000-113,400
Straw yield	Kg	5195.55	5061.65	4691.65	91701.46	89338.12	82807.62	NA	NA	NA	NA	NA	NA

Table 4: Mean of yield differences between the production year of 2021, and 2022

Output Energy	Season I (2021)	Season II (2022)
Grain yield, kg/ha	409.9±37.4 A	567.3±40 B
Straw yield, kg/ha	390.1±37.4 A	506.8±36.2 B

Table 5: Analysis of Variance of Amounts of Input and output energy

TS	Human labor (hr)	Diesel fuel (lit)	Field Operation (hr)	Pesticide (lit)	Grain Yield (kg)	Straw yield (kg)
CT	109.31±4.54A	46.293±1.44A	7.78±0.2A	0.005±0.0055A	500.9±80.6A	467.6±59.7A
MT	111.22±11.97A	41.668±1.76B	7.66±0.15A	0.005±0.0055A	499.1±106.6A	455.2±82.8A
NT	90.9±40.3A	31.022±1.13C	6.58±0.11B	0.005±0.0055A	465.8±91.1A	422.2±69.6A

Table 6: Energy Indices of different tillage systems for Faba Bean Production

Energy indices	CT	MT	NT
NEG (GJ/ha)	17823.28±2581.55A	17575.55±3574.48A	16337.41±2993.94A
EUE	40.82±6.12A	40.65±9.29A	39.04±8.10A
SE(MJ/kg)	0.045±0.008A	0.047±0.012A	0.048±0.011A
EP(kg/MJ)	22.39±22.40A	22.53±22.53A	21.69±21.70A
EPF	39.82±6.12A	39.65±9.29A	38.04±8.10A

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(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Fig. 1(a-i) Sample preparation methodology faba bean energy consumption determination

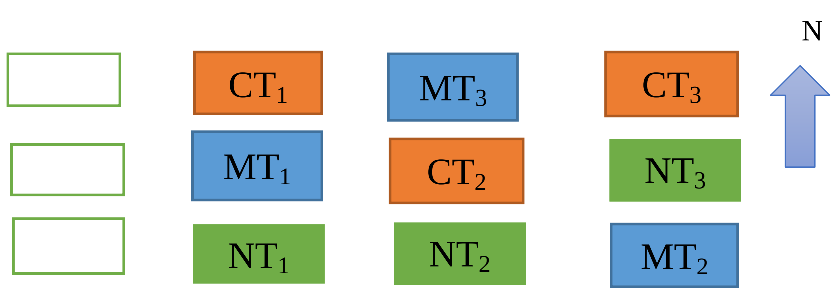


Figure 2. : Field Experiment Design

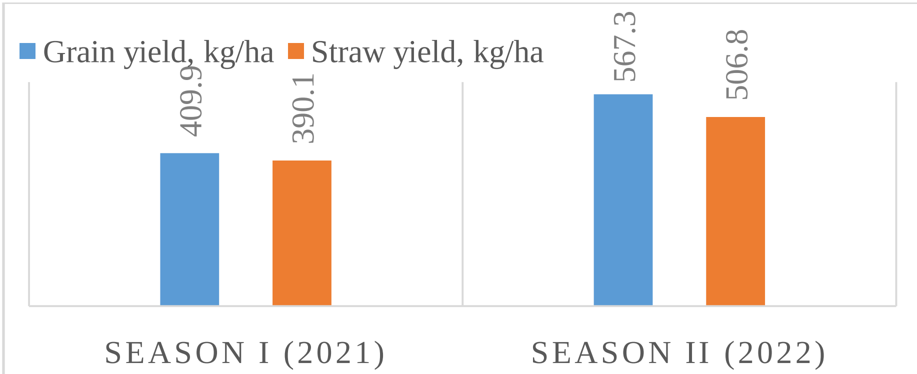


Figure 3: Season-based yield difference/Productivity

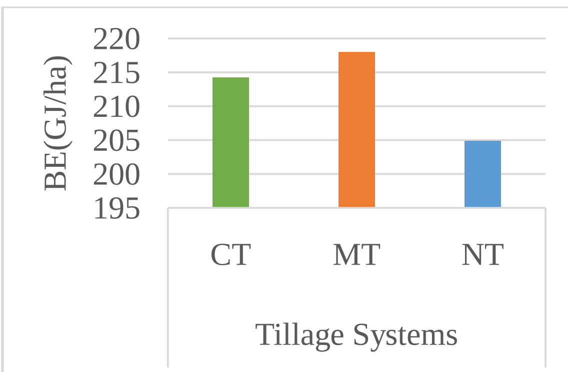


Figure 4: Effects of Tillage Systems on Biological Energy

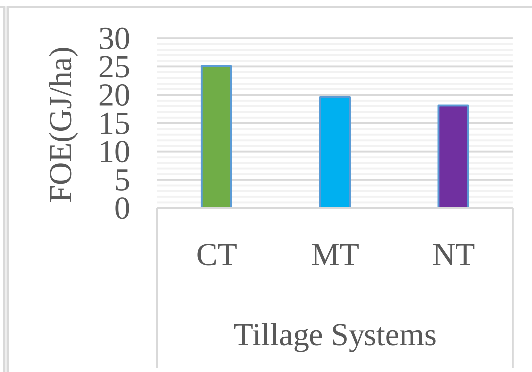


Figure 5: Effects of Tillage Systems on Field Operation Energy

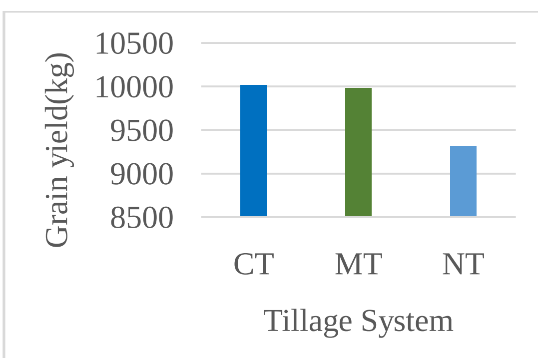


Figure 6: Effects of Tillage Systems on Grain Yield

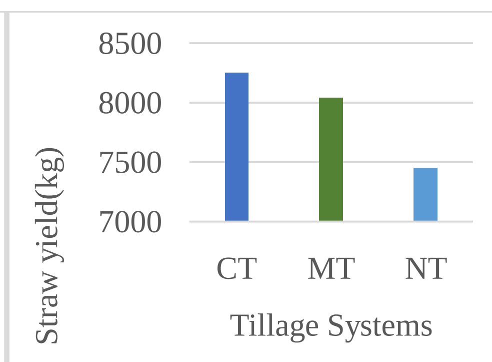
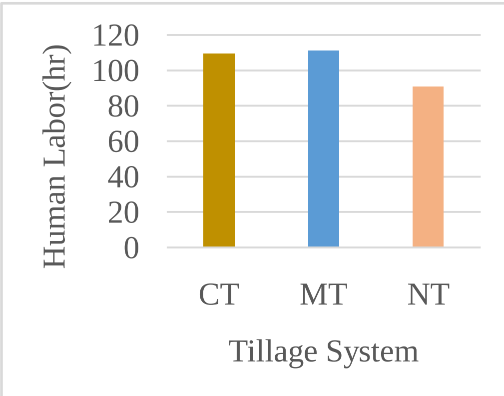


Figure 7: Effects of Tillage Systems on Straw Yield



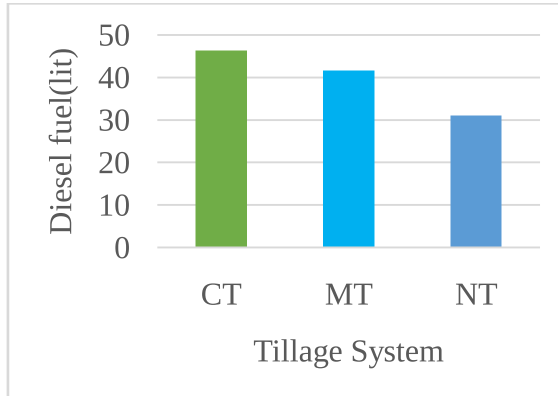
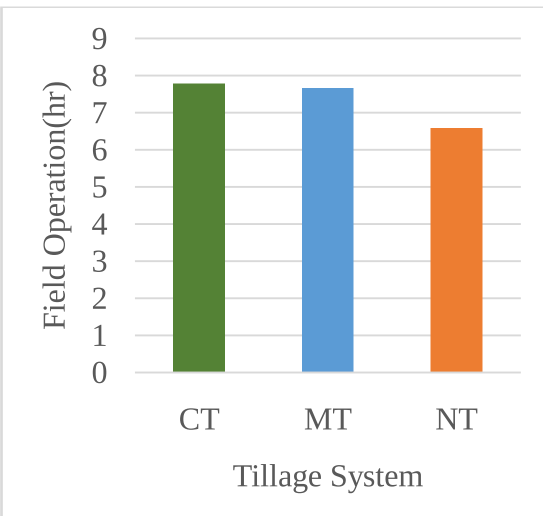


Figure 8: Effects of Tillage onSystems on human labor

Figure 9: Effects of Tillage Systems on Diesel Fuel



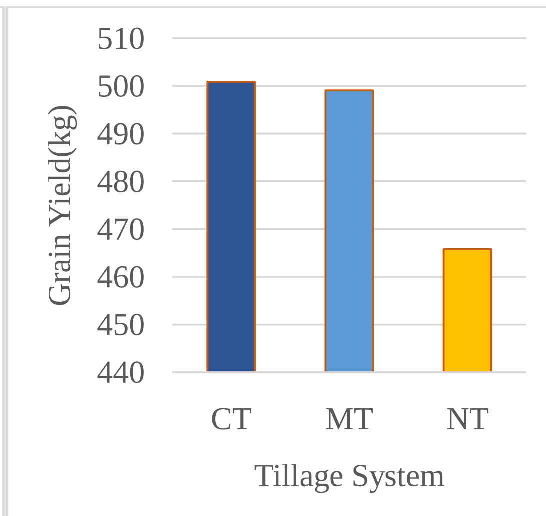


Figure 10: Effects of Tillage Systems onFigure 11: Effects of Tillage Systems onField Operation Grain Yield

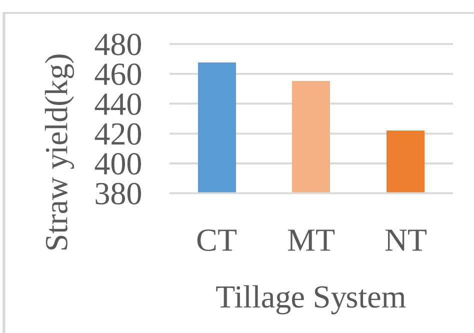
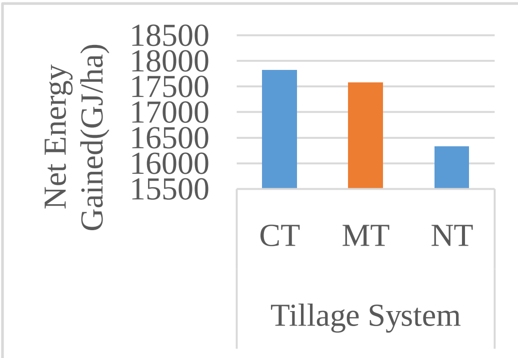


Figure 12: Effect of Tillage Systems on Straw Yield.



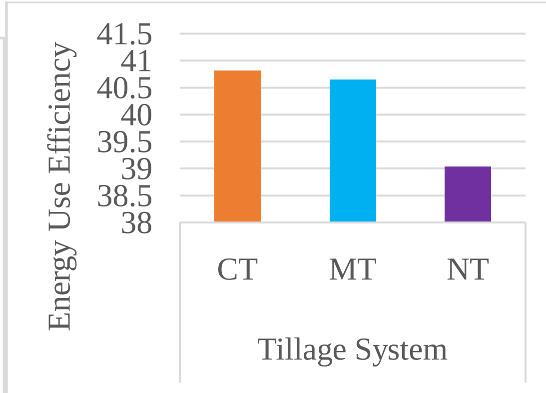
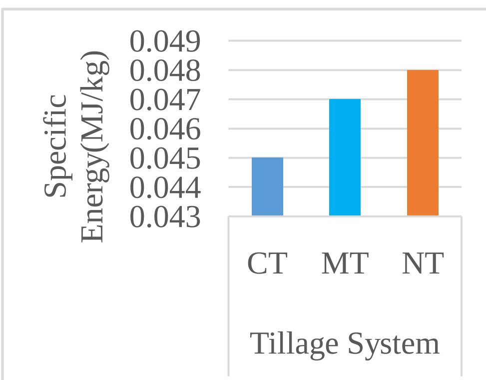


Figure 13: Effects of Tillage Systems on Net Energy Gained

Figure 14: Effects of Tillage Systems on Energy Use Efficiency



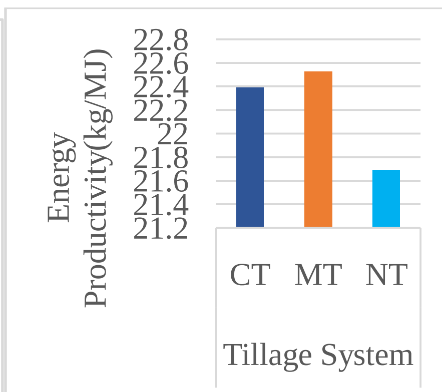


Figure 15: Effects of Tillage Systems on Specific Energy

Figure 16: impacts of Tillage Systems on Energy Productivity

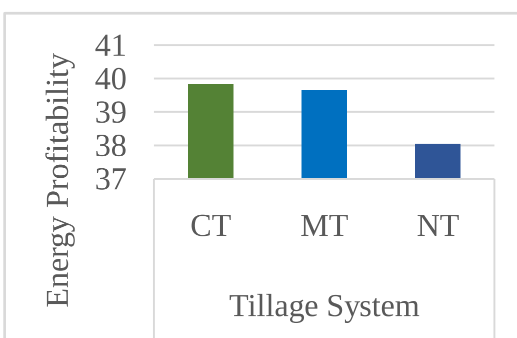


Figure 17: Effects of Tillage Systems on Energy Profitability