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Determination of energy balance of common vetch (*Vicia sativa* L.), hungarian vetch (*Vicia pannonica* C.) and narbonne vetch (*Vicia narbonensis* L.) production in Turkey

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ABSTRACT

The aim of this study is to determine an energy balance of common vetch, hungarian vetch and narbonne vetch production during the production season of 2015 in Bingol province of Turkey. The energy input in common vetch, hungarian vetch and narbonne vetch production have been calculated as 13060.72 MJ ha^{-1}, 15767.22 MJ ha^{-1}and 14769.73 MJ ha^{-1}, respectively. The energy output in common vetch, hungarian vetch and narbonne vetch production have been calculated as 42048.22 MJ ha^{-1}, 10051.33 MJ ha^{-1} and 11963.62 MJ ha^{-1}, respectively. Energy usage efficiency, specific energy, energy productivity and net energy values related to common vetch, Hungarian vetch and Narbonne vetch production have been determined as 3.22, 0.64, 0.81; 5.46 MJ kg^{-1}, 29.98 MJ kg^{-1}, 21.98 MJ kg^{-1}; 0.18 kg MJ^{-1}, 0.03 kg MJ^{-1}, 0.05 kg MJ^{-1} and 28987.50 MJ ha^{-1}, -5715.89 MJ ha^{-1}, -2806.11 MJ ha^{-1} respectively for each type. The total renewable energy input applied in common vetch, hungarian and narbonne vetch was 26.85, 20.42 and 29.69 per cent, respectively.

Key words: Common vetch, Energy balance, Hungarian vetch, Narbonne vetch, Specific energy, Turkey.

INTRODUCTION

Vetch species have a great importance in terms of providing for the good quality coarse and concentrate fodder need for stock breeding. Due to its richness in variety, adaptation ability, grass and seed productivity and other similar reasons, vetch is being planted and produced at higher levels in our coastal and central regions. In transition regions with an annual precipitation level of 400 mm or more, where grain-fallow system is practised, hungarian vetch (*Vicia pannonica* C.), hairy vetch (*Vicia villosa* R.), narbonne vetch (*Vicia narbonensis* L.) and common vetch (*Vicia sativa* L.) is being cultivated as sole crop or together with barley, oat and triticale to produce fodder or seed (Iptas ve Yilmaz, 1998; Buyukburc and Iptas, 2001; Buyukburc and Karadag, 2002; Buyukburc *et al.,* 2004). Among these varieties, hungarian vetch, hairy vetch and narbonne vetch are particular winter crops. On the other hand, common vetch has a lower winter resistance than the other vetch varieties therefore it is planted during summer months (Acikgoz, 2001; Buyukburc *et al.,* 2004). The total size of pasture area in the world is 3.40 billion hectare. Turkey's total pasture area size is 14.60 million ha, total size of forage plant area is 1.87 m ha, while the amount of production is 38.91 m tons. The total area of vetch in Turkey is 499 043 ha and production of 4.49 m tons which contributes 27% in total forage production in the country. (Anonymous, 2014; Baran, 2016).

Energy efficiency analysis is closely associated with economic and ecological aspects of the chosen farming systems. Energy efficiency and energy balance can be accepted as a vital tool to define the environmental impacts of farming systems. Determination of the energy efficiency makes it possible to compare different farming systems in environment friendly production as well as sustainability of non-renewable natural resources (Celik *et al*., 2010). To determine energy efficiency, energy input-output analyses are usually conducted. These analyses determine how efficiently energy is used (Pervanchon *et al.,* 2002; Beigi *et al.,* 2016). Energy usage efficiency and related efficiency have been carried out by researchers on common vetch, hungarian vetch and narbonne vetch. Some of these researches may be listed as those on the energy usage research of vetch (Baran, 2016), corn (Ozturk *et al.,* 2006), canola (Unakitan *et al.,* 2010), soybean (Mandal *et al.,* 2002), sesame (Akpinar *et al.,* 2009), potato (Mohammadi *et al.,* 2008),barley (Mobtaker *et al.,* 2010), sugar beet (Haciseferogullari *et al.,* 2003), chick pea (Marakoglu *et al.,* 2010), sunflower (Uzunoz *et al.,* 2008)etc. This study does not contain any research regarding the energy usage

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analysis of common vetch, hungarian vetch and narbonne vetch production in Turkey.

MATERIALS AND METHODS

This study has been performed for the whole Bingol province of Turkey (E41°-20′-39°-56°; N39°-31′; 36°-28° 1151 m above sea level(Anonymous, 2016a). The daily difference between highest temperature and lowest temperature has nearly 20⁰C. The annual average temperature of the province is 12.1 ⁰C while the annual average precipitation level is 873.70 mm (Anonymous, 2016b).Soil structure of the province is clay-loam and loamy(Ates and Turan, 2015).The researches performed on trials area have 627 (common vetch), 255 (hungarian vetch) and 285(narbonne vetch) square meters, located at Bingol in 2015 (Hungarian vetch 2014-2015 production season). Randomized Complete-Block Design with three replicates has been performed in this study.Human labour, machinery, chemical fertilizers, diesel fueland seed energy have beencomputed inputs.Common vetch, hungarian vetch and narbonneyieldshave been computedas output.In Table 1, the agricultural production inputs, energy equivalents of input and outputhave beenusedas energy values. By adding energy equivalents of all inputs in MJ unit, the total energy equivalents have beencomputed.) The energy ratio (energy usage efficiency), energy productivity, specific energy and net energy have been computedby using the following equations (Mandal *et al.,* 2002; Mohammadi *et al.,* 2008 and Mohammadi *et al.* 2010)

Energy efficiency =
Energy output (MJ ha^{-1}) / Energy input (MJ ha^{-1}) (1)

Energy productivity =
Yield output (kg ha^{-1}) / Energy input (MJ ha^{-1}) (2)

Specific energy =
Energy input (MJ ha^{-1}) / Yield output (kg ha^{-1}) (3)

Net energy =
Energy output (MJ ha^{-1}) - Energy input (MJ ha^{-1}) (4)

Kocturk and Engindeniz (2009) reported that the input energy can also be classified into direct, indirect, renewable andnon-renewable forms(Mandal *et al.,* 2002; Singh *et al.,* 2003)". Total fuel consumption of each parcel has beencomputed as l ha^{-1}. Full tank method has been used to measure the amount of fuel used (Gokturk, 1999; El Saleh, 2000; Sonmete, 2006). Labor time of each parcel (ha h^{-1}) has been calculated by proportion the total time computed for in area of the trial to the areas amount. Using the effective labour time (t_{ef}), while experiments in parcelshave beendone(Sonmete, 2006; Guzel, 1986; Ozcan, 1986). Measuringthe time spent duringagricultural operations in the parcels have been performed with the aid of chronometer (Sonmete, 2006). For calorific values of common vetch, hungarian vetch and narbonne vetch IKA brand C200 model bomb calorimeter device has been used. For measuring purposes, the amount of fuel (~0.1 g) has been combusted inside the calorimeter bomb. The device has been given a calorific value in MJ kg^{-1} unit. For samples, reading of the calorific value has been measured repetitively for 3 times and then the average value have been reported in common vetch, hungarian vetch and narbonne vetch study.

RESULTS and DISCUSSION

The amounts of Common vetch, Hungarian vetch and Narbonne vetch produced per hectare during the 2015 production season have been determined as 2394 kg, 526 kg and 672 kg on average, respectively. The energy balances of common vetch, Hungarian vetch and Narbonne vetch production related to this study are given in Table 2. These findings suggest that the highest energy inputs in common vetch production are as follows: diesel fuel energy by 30.94%, machinery energy by 23.74%, chemical fertilizers energy by 18.47%, human labour energy by 13.40% and seed energy by 13.45%. It can also be suggested that the highest energy inputs in Hungarian vetch production are as follows: diesel fuel energy by 31.51%, machinery energy by 24.17%, chemical fertilizers energy by 23.90%, human labour energy by 10.72% and seed energy by 9.70%. Finally the highest energy inputs in Narbonne vetch production are as follows: diesel fuel energy by 30.10%, seed energy by 24.11%, machinery energy by 23.09%, chemical fertilizers energy by 17.12% and human labour energy by 5.59%. It can be concluded that the highest energy inputs in common vetch, Hungarian vetch and Narbonne vetch production are as

Table 1: Energy equivalents of inputs and outputs in common vetch, hungarian vetch and narbonne vetch production

Inputs and outputs	Unit	Energy equivalent Coefficient	Sources
Inputs	Unit	Values(MJ $unit^{-1}$)	Sources
Human labour	h	1.96	(Karaagac *et al*., 2011; Mani *et al*., 2007)
Machinery	h	64.80	(Singh, 2002; Kizilaslan, 2009)
Chemical fertilizers			
Nitrogen	kg	60.60	(Singh, 2002)
Phosphorous	kg	11.10	(Singh, 2002)
Diesel fuel	l	56.31	(Singh, 2002; Demircan *et al.,* 2006)
Common seed	kg	17.564	Measured
Hungarian seed	kg	19.109	Measured
Narbonne seed	kg	17.803	Measured

Table 2: Energy balance in common vetch, hungarian vetch and narbonne vetch production

Inputs	Common vetch		Hungarian vetch		Narbonne vetch	
	Energy value ($MJ\ ha^{-1}$)	**Ratio (%)**	**Energy value ($MJ\ ha^{-1}$)**	**Ratio (%)**	**Energy value ($MJ\ ha^{-1}$)**	**Ratio (%)**
Human labour	1750.55	13.40	1690.97	10.72	825.26	5.59
Machinery	3100.03	23.74	3811.54	24.17	3410.42	23.09
Chemical fertilizers	2412.92	18.47	3767.76	23.90	2528.33	17.12
Nitrogen	1643.47	12.58	2566.41	16.28	1722.25	11.66
Phosphorous	769.45	5.89	1201.35	7.62	806.08	5.46
Diesel fuel	4040.81	30.97	4968.23	31.51	4445.11	30.10
Seed	1756.40	13.45	1528.72	9.70	3560.60	24.11
Total inputs	13060.72	100.00	15767.22	100.00	14769.73	100.00
Outputs	**Energy value ($MJ\ ha^{-1}$)**	**Ratio (%)**	**Energy value ($MJ\ ha^{-1}$)**	**Ratio (%)**	**Energy value ($MJ\ ha^{-1}$)**	**Ratio (%)**
Yield	42048.22	100.00	10051.33	100.00	11963.62	100.00

follows: diesel fuel energy, machinery energy and chemical fertilizers energy.

Human labour and diesel fuel energy have been utilized for tractor and farm operations. As Table 3 indicates, the amount of chemical fertilizers used for common vetch, Hungarian vetch and Narbonne vetch production were 96.44, 150.58 and 101.04 kg ha^{-1}. Common vetch yield, energy input, energy output, energy use efficiency, specific energy, energy productivity and net energy used for common vetch production have been calculated as 2394 kg ha^{-1}, 13060.72 MJ ha^{-1}, 42048.22 MJ ha^{-1}, 3.22, 5.46 MJ kg^{-1}, 0.18kg MJ^{-1} and 28987.50 MJ ha^{-1}, respectively. In Hungarian vetch production, Hungarian vetch yield, energy input, energy output, energy efficiency, specific energy, energy productivity and net energy have been calculated as 526 kg ha^{-1}, 15767.22 MJ ha^{-1}, 10051.33 MJ ha^{-1}, 0.64, 29.98 MJ kg^{-1}, 0.03 kg MJ^{-1} and -5715.89 MJ ha^{-1}, respectively. And in Narbonne vetch production, Narbonne vetch yield, energy input, energy output, energy efficiency, specific energy, energy productivity and net energy have been calculated as 672 kg ha^{-1}, 14769.73 MJ ha^{-1}, 11963.62 MJ ha^{-1}, 0.81, 21.98 MJ kg^{-1}, 0.05 kg MJ^{-1} and -2806.11 MJ ha^{-1}, respectively.

The distribution of input energies, applied in accordance with the direct, indirect, renewable and non-renewable energy groups during the production of common vetch, Hungarian vetch and Narbonne vetch, are given in Table 4. The total energy input applied in common vetch, Hungarian vetch and Narbonne vetch production could be classified as 44.34%, 42.23% and 35.68% direct energy, respectively. The total energy input applied in common vetch, Hungarian vetch and Narbonne vetch production could be classified as 55.66%, 57.77% and 64.32% indirect energy, respectively. The total energy input applied in common vetch, Hungarian vetch and Narbonne vetch production could be classified as 26.85%, 20.42% and 29.69% renewable energy, respectively. The total energy input applied in common vetch, Hungarian vetch and Narbonne vetch production could be classified as 73.15%, 79.58% and 70.31% non-renewable energy, respectively. Similarly, it has been determined that the ratio of non-renewable energy was higher than the ratio of renewable energy and the ratio of indirect energy was higher than the ratio of direct energy in barley (Baran and Gokdogan, 2014), wheat (Ghorbanie *et al*., 2011), maize (Vural and Efecan, 2012), sesame (Akpinar *et al*., 2009), rice (Pisghar-Komleh *et al*., 2011) etc.

In this research, the energy balance analysis of common vetch, Hungarian vetch and Narbonne vetch production has been conducted and then compared to each other. The acquired findings suggest that common vetch production is profitable in terms of energy use efficiency, with an efficiency value of 3.22. In contrast, however,

Table 3: Energy balance calculations in common vetch, hungarian vetch and narbonne vetch production

Computes	Unit	Common vetch Values	Hungarian vetch Values	Narbonne vetch Values
Yields	kg ha^{-1}	2394	526	672
Energy input	MJ ha^{-1}	13060.72	15767.22	14769.73
Energy output	MJ ha^{-1}	42048.22	10051.33	11963.62
Energy use efficiency	-	3.22	0.64	0.81
Specific energy	MJ kg^{-1}	5.46	29.98	21.98
Energy productivity	kg MJ^{-1}	0.18	0.03	0.05
Net energy	MJ ha^{-1}	28987.50	-5715.89	-2806.11

Table 4: Energy inputs in the form of direct, and indirect renewable and non-renewable energy for common vetch, hungarian vetch and narbonne vetch production

Type of energy	Common vetch		Hungarian vetch		Narbonne vetch	
	Energy input (MJ ha^{-1})	Ratio (%)	Energy input (MJ ha^{-1})	Ratio (%)	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy [a]	5791.36	44.34	6659.20	42.23	5270.37	35.68
Indirect energy [b]	7269.36	55.66	9108.02	57.77	9499.36	64.32
Total	13060.72	100.00	15767.22	100.00	14769.73	100.00
Renewable energy [c]	3506.95	26.85	3219.69	20.42	4385.86	29.69
Non-renewable energy [d]	9553.76	73.15	12547.73	79.58	10383.87	70.31
Total	13060.72	100.00	15767.22	100.00	14769.73	100.00

[a] Includes human labour and diesel fuel; [b] Includes seed, chemical fertilizers and machinery;
[c] Includes human labour and seed; [d] Includes diesel fuel, chemical fertilizers and machinery.

Hungarian vetch and Narbonne vetch production is not profitable in terms of energy use efficiency, with respective values of 0.64 and 0.81. Based on the assessment of trial results, common vetch production is more profitable than Hungarian vetch and Narbonne vetch production. In previous studies, Baran and Gokdogan (2014) calculated energy output / input ratio as 5.44 for barley, Ghorbanie *et al*. (2011) calculated energy output / input ratio as 2.56; 1.97 for wheat, Vural and Efecan (2012) calculated energy output / input ratio as 0.76 for maize, Akpinar *et al*. (2009) calculated energy output / input ratio as 1.80; 1.40 for sesame, Pisghar-Komleh *et al*. (2011) calculated energy output / input ratio as 1.53 etc.

Several previous studies related to common vetch, Hungarian vetch and Narbonne vetch production concluded that diesel energy, machinery energy and chemicals fertilizers energy have the highest inputs. Demircan *et al*. (2006) noted, "Accurate fertilization management, knowing the right amount and timing of fertilization (Kitani, 1999) and proper selection of tractor and sound management of machinery are needed to reduce direct use of diesel fuel (Isik and Sabanci, 1991), thus saving non-renewable energy sources without impairing the yield or profitability, whilst improving the energy use efficiency in sweet cherry production". These assertions may be effectively applied for common vetch, Hungarian vetch and Narbonne vetch production with the purpose of lowering the amounts of related inputs.

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