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Energy Production, Consumption and Yield of Maize under Different Planting Density and Fertilizer Levels

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Abstract A field trail was conducted during *kharif* seasons of 2017 to assess the energy production, consumption and yield of maize under various plant population and fertilizer levels. The experiment was conducted in Randomized Block Design and replicated thrice. The field trail was taken up with nine treatments which comprised of four different spacings with one or two plants per hill and various fertilizer doses. The experimental results showed that 30 cm × 25 cm (one seeding hill^{-1}) with 200% RDF registered more energy output, net energy, energy intensity with maximum grain and stover yield of maize. Planting geometry of 60 cm × 25 cm (two seeding hill^{-1}) with 200% RDF consumed higher input and produced higher specific energy.

Keywords Energy efficiency, Fertilizer levels, Net energy, Seedlings per hill, Yield.

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Introduction

At global level maize occupied third position in its grain production after rice and wheat. Maize is grown in almost all the countries with various environmental conditions. It is not only consumed by human being as food grain, but also used as feed for livestock as forage crop. Maize is a C_4 crop and it has yielding potential naturally. Even though the average productivity in India is low, as compared to other maize growing countries, due to many constraints like imbalanced use of fertilizers, lack of optimal crop stand and optimum planting geometry (Mangal et al. 2017). Successful maize production requires an understanding of various management practices as well as environmental conditions that affect crop performance (Ecker 1995). Appropriate plant population and planting geometry are the important cultural practices which affect yield potential of maize and its stability (Norwood 2001). Since the age of subsistence agriculture to present day cultivation, energy is a key input for agriculture, which is positively correlated with energy input. Agriculture is both a producer and consumer of energy (Taheri Garav et al. 2010).

In recent years, many researchers have investigated on energy in relation to crop production (Liu et al. 2010). For sustainable agricultural production, energy use efficiency is one of the main principle. Two types of energy are direct and indirect energy. Fuel, electricity is the direct energy which directly used on the land like land preparation, irrigation, harvesting, processing (Shafique et al. 2015). Indirect energy used in crop production are packing and transporting of fertilizers, seeds, machineries and pesticides (Ozkan et al. 2004).

Input - output analysis of energy is used to determine how efficiently the energy is used (Morteza et al. 2012). Franzluebbers and Francis (1995) studied that energy requirements for various cereal crops like maize and sorghum management systems in USA and they concluded that decreased energy ratio was observed with N fertilizer application, except with cereal as previous crop and low soil available N at initial. Canakci et al. (2005) studied the energy use patterns in Turkey with wheat, cotton, maize and sesame crops. They noticed that in all input energies, 52.7% of share was used for fertilizer application in maize alone. On this basis, the main objective of this study was to evaluate energy use pattern and production of maize under various plant populations with fertilizer levels.

Materials and Methods

The field experiment was conducted under irrigated condition during the period from July to October (*kharif* seasons) of 2017 and 2018. The site of field trail was located in Southern region of the country, Western Agro Climatic Zone of Tamil Nadu at 11^0N latitude, 77^0E longitude with an altitude of 426.7 m above mean sea level. The soil of the experimental site was sandy loam texture. In both the years, the field had been in tillage by tractor drawn cultivator followed by rotavator to get a favorable texture for crop growth. The initial soil sample analysis of experimental location revealed that soil was alkaline in pH (8.54) with low soluble salts (0.18 dS m^{-1}), medium in available organic carbon content (0.60%), low in soil available nitrogen (246 kg ha^{-1}), medium in soil available phosphorus (11 kg ha^{-1}) and high in soil available potassium (421 kg ha^{-1}).

Randomized Block Design was used for experiment with three replications in both the years. The field trail was taken up with nine combinations of different plant density by altering geometry and incorporating one or two seedlings per hill with various fertilizer levels viz., 60 cm × 25 cm with one seeding $hill^{-1}$ and 100% RDF (T_1), 60 cm × 25 cm with two seedlings $hill^{-1}$ and 150% RDF (T_2), 60 cm × 25 cm with two seedlings $hill^{-1}$ and 200% RDF (T_3), 60 cm × 40 cm with two seedling $hill^{-1}$ and 125% RDF (T_4), 60 cm × 40 cm with two seedlings $hill^{-1}$ and 150% RDF (T_5), 30 cm × 25 cm with one seeding $hill^{-1}$ and 150% RDF (T_6), 30 cm × 25 cm with one seeding $hill^{-1}$ and 200% RDF (T_7), 45 cm ×30 cm with one seeding $hill^{-1}$ and 100% RDF (T_8) and 45 cm × 30 cm with one seeding $hill^{-1}$ and 125% RDF (T_9). TNAU maize hybrid Co 6 used as test variety.

Gross plot size was 3.6 m × 6.0 m wherein various inter and intra row spacings were followed. Data collections during the field investigation were noted on the basis of grain yield and energy relation as followed.

$$\text{Specific energy (MJ kg}^{-1}\text{)} = \frac{\text{Energy input (MJ ha}^{-1}\text{)}}{\text{Grain yield (kg ha}^{-1}\text{)}}$$

$$\text{Net energy (MJ ha}^{-1}\text{)} = \text{Energy output (MJ ha}^{-1}\text{)} - \text{Energy input (MJ ha}^{-1}\text{)}$$

$$\text{Energy intensity (MJ □}^{-1}\text{)} = \frac{\text{Energy output (MJ ha}^{-1}\text{)}}{\text{Cultivation expenses (□ ha}^{-1}\text{)}}$$

$$\text{Energy productivity (kg MJ}^{-1}\text{)} = \frac{\text{Output (grain + byproduct) (kg ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

The data required for energy analysis was collected by using the method suggested by Kalbande and More (2008), Devasenapathy et al. (2009). Input energy (machinery, seeds, fertilizer, water, chemicals and labor) and output energy (grain and stover) for the purpose of analysis were calculated by using energy equivalents and expressed in Mega Joules (MJ ha^{-1}). Energy efficiency was calculated by taking ratio of input and output energy for the each treatment (Dazhong and Pimental 1984). Based on the energy equivalents of the inputs and output (s), energy productivity, specific energy and net energy gain were calculated (Mohammadi and Omid 2010).

Results and Discussion

Input energy

Energy relations of maize under various planting geometry and fertilizer levels were given in Table1.

Table 1. Effect of different planting density and fertilizer levels on input (MJ ha^{-1}), output (MJ ha^{-1}) and specific energy (MJ kg^{-1}).

Treatments	Energy input	Energy output	Specific energy
T_1 : 60 cm × 25 cm – one seeding $hill^{-1}$ with 100% RDF	39270	209860	6.39
T_2 : 60 cm × 25 cm – two seeding $hill^{-1}$ with 150% RDF	59051	277352	8.07
T_3 : 60 cm × 25 cm – two seeding $hill^{-1}$ with 200% RDF	78539	304221	9.84
T_4 : 60 cm × 40 cm – two seeding $hill^{-1}$ with 125% RDF	49087	243860	7.20
T_5 : 60 cm × 40 cm – two seeding $hill^{-1}$ with 150% RDF	58831	261271	8.32
T_6 : 30 cm × 25 cm – one seeding $hill^{-1}$ with 150% RDF	58757	286268	7.81
T_7 : 30 cm × 25 cm – one seeding $hill^{-1}$ with 200% RDF	78245	318265	9.44
T_8 : 45 cm × 30 cm – one seeding $hill^{-1}$ with 100% RDF	39302	224585	6.18
T_9 : 45 cm × 30 cm – one seeding $hill^{-1}$ with 125% DRF	49046	238018	7.43

Results showed that 60 cm × 25 cm–two seeding $hill^{-1}$ with 200% RDF consumes more energy (78539 MJ ha^{-1}) followed by 30 cm × 25 cm–one seeding $hill^{-1}$ with 200 % RDF for maize production as compared to other planting geometries and fertilizer doses. This might be due to higher dosage of recommended fertilizers and higher amount of seed used. Recommended spacing (control) was 60 cm × 25 cm–one seedling per $hill^{-1}$ with 100% RDF. When adopting two seedlings $hill^{-1}$ with 200% RDF in recommended spacing consumes more energy than control. Whereas, lower energy input was observed with 45 cm × 30 cm–one seeding $hill^{-1}$ with 100% RDF which registered 39302 MJ ha^{-1}. The reason might be due to less seed rate and fertilizer dose. This was in agreement with the findings of Mangal et al. (2017).

Output energy

In terms of output energy, geometry of 30 cm × 25 cm –one seeding $hill^{-1}$ with 200% RDF recorded higher energy output of 3,18.265 MJ ha^{-1} (Table 1) due to higher maize grain yield produced. Productivity per plant was low but production per unit area was high due to higher plant population which leads to higher total productivity in geometry of 30 cm × 25 cm– one seeding $hill^{-1}$ with 200% RDF than normal spacing. However, 60 cm × 25 cm - one seeding $hill^{-1}$ with 100% RDF recorded lower output energy (2,09,860 MJ ha^{-1}). These differences in energy output might be due to higher grain and stover yield production which resulted in increased output energy. This was in agreement with the findings of Jayadeva et al. (2010), Sangeetha (2013).

Specific energy

Energy required to produce one kg of main product of each treatments is expressed as specific energy (Table 1). With respect to specific energy, lower specific energy of 6.39 MJ kg^{-1} was noticed under 60 cm × 25 cm– one seeding $hill^{-1}$ with 100% RDF. In both the treatments the population (1,33,333 plants ha^{-1}) and fertilizer doses was same. Higher specific

Table 2. Effect of different planting density and fertilizer levels on net energy (MJ ha^{-1}), energy intensity (MJ Rs^{-1}), energy productivity (kg MJ^{-1}) and energy efficiency.

Treatments	Net energy	Energy intensity	Energy productivity	Energy efficiency
T_1 : 60 cm × 25 cm – one seeding $hill^{-1}$ with 100% RDF	170590	5.39	2.30	5.34
T_2 : 60 cm × 25 cm – two seeding $hill^{-1}$ with 150% RDF	218300	6.01	1.82	4.70
T_3 : 60 cm × 25 cm – two seeding $hill^{-1}$ with 200% RDF	225682	6.04	1.49	3.87
T_4 : 60 cm × 40 cm – two seeding $hill^{-1}$ with 125% RDF	194773	5.84	2.04	4.97
T_5 : 60 cm × 40 cm – two seeding $hill^{-1}$ with 150% RDF	202440	5.96	1.77	4.44
T_6 : 30 cm × 25 cm – one seeding $hill^{-1}$ with 150% RDF	227510	6.20	1.88	4.87
T_7 ; 30 cm × 25 cm – one seeding $hill^{-1}$ with 200% RDF	240020	6.32	1.56	4.07
T_8 : 45 cm × 30 cm – one seeding $hill^{-1}$ with 100% RDF	185283	5.72	2.38	5.71
T_9 : 45 cm × 30 cm – one seeding $hill^{-1}$ with 125% RDF	188972	5.76	1.98	4.85

energy was observed with 60 cm × 25 cm– two seeding hill^{-1} with 200% RDF (9.84 MJ kg^{-1}) which was followed by 30 cm × 25 cm – one seeding hill^{-1} with 200% RDF (9.44 MJ kg^{-1}). The difference in specific energy might be due to more competition for nutrients when two seedlings per hill with wider spacing were maintained than single seedling per hill with closer spacing adopted.

Net energy and energy intensity

By deducting energy input from energy output of particular treatment, net energy was obtained and energy intensity is ratio between output energy and cultivation expenses (Table 2). Higher net energy and energy intensity of 2,40,020 MJ ha^{-1} and 6.32 MJ Rs^{-1}, respectively was observed in 30 cm × 25 cm–one seeding hill^{-1} with 200% RDF due to higher grain and stover yield. In closer spacing and one seedling hill^{-1} with double the fertilizer level and plant population than control, per plant input use efficiency was more due to less interplant competition as compared to adopting two seedlings hill^{-1}. It was followed by 30 cm × 25 cm–one seeding hill^{-1} with 150% RDF (2,27,510 MJ ha^{-1} and 6.20 MJ Rs^{-1}, respectively). Plant geometry of 60 cm × 25 cm–one seeding hill^{-1} with 100% RDF (control) recorded lower net energy and energy intensity of 1,70,590 MJ ha^{-1} and 5.39 MJ Rs^{-1}, respectively. The energy use efficiency of per plant was less due to wider spacing in recommended plant population with 100% RDF.

Energy productivity and energy efficiency

Energy productivity is quantity of output for every unit of input (Table 2). Planting geometry of 45 cm × 30 cm–one seeding hill^{-1} with 100% RDF recorded higher energy productivity and energy efficiency (2.38 kg MJ^{-1} and 5.71, respectively). The result of this treatment indicated that energy efficiency increased as the plant population decreased. This result corroborates with Mangal et al. (2017) who reported that energy use efficiency increased linearly as the planting geometry decreased. Lower energy productivity and energy efficiency was observed with geometry of 60 cm × 25 cm– two seeding hill^{-1} with 200% RDF (1.49 kg MJ^{-1} and 3.87, respectively) in maize production system due to higher input energy consumed.This is in line with findings of Lorzadeh et al. (2011).

Table 3. Effect of different planting density and fertilizer levels stover yield (kg ha^{-1}) and grain yield (kg ha^{-1}) of maize.

Treatments	Stover yield	Grain yield
T_1 : 60 cm × 25 cm– one seeding hill^{-1} with 100% RDF	9556	6150
T_2 : 60 cm × 25 cm–two seeding hill^{-1} with 150% RDF	13581	7319
T_3 : 60 cm × 25 cm–two seeding hill^{-1} with 200% RDF	14952	7981
T_4 : 60 cm × 40 cm–two seeding hill^{-1} with 125% RDF	11492	6817
T_5 : 60 cm × 40 cm–two seeding hill^{-1} with 150% RDF	12585	7072
T_6 : 30 cm × 25 cm–one seeding hill^{-1} with 150% RDF	14052	7525
T_7 : 30 cm × 25 cm–one seeding hill^{-1} with 200% RDF	15711	8291
T_8 : 45 cm × 30 cm– one seeding hill^{-1} with 100% RDF	10491	6357
T_9 : 45 cm × 30 cm–one seeding hill^{-1} with 125% RDF	11281	6599
SEd	456	299
CD (p=0.05)	966	633

Grain and stover yield

Grain and stover yield of maize under different planting geometry and fertilizer levels are presented in Table 3. Planting geometry of 30 cm × 25 cm (one seeding hill^{-1}) with application 200% RDF produced higher grain (8291 kg ha^{-1}) and stover yield (15711 kg ha^{-1}) and it was at par with 60 cm × 25 cm–two seeding hill^{-1} with 200% RDF (7981 and 14952 kg ha^{-1}, respectively), Narrow planting geometry had significantly greater stover yield (13.6 t ha^{-1}) as matched to wider planting geometry (9.00 t ha^{-1}). Higher dry matter production per unit area was obtained by increasing plant population with sufficient plant nutrients and favorable environmental conditions. This result shows that higher plant density and N was advantageous for optimum yield (Zeleke et al. 2018). Whereas, lower grain and stover yield of 6150 and 9556 kg ha^{-1} respectively was observed with geometry of 60 cm × 25 cm (one seeding hill^{-1}) with 100 % RDF. The highest plant density with higher nitrogen applied plot recorded maximum grain yield and the lowest yield was obtained from lower plant population. This is line with findings of Bozorgi et al. (2011)

Conclusion

Based on the experimental results, it may be concluded that geometry of 30 cm × 25 cm–one seeding hill^{-1} with 200% RDF was observed more output energy, net energy, energy intensity, higher grain and stover yield. So, this treatment found to be an ideal agronomic options to save energy, higher yield in maize which is economically viable, sustainable and productive to the farmers of Western zone of Tamil Nadu.

References

Bozorgi HR, Dousta HZ, Sadeghi SM, Keshavarz A, Faraji A (2011) Study effect of pant density and nitrogen fertilizer on yield and yield components of maize. World Appl Sci J 13: 147—151.

Canakci M, Topakci M, Akinci I. Ozmerzi A (2005) Energy use pattern of some field crops and vegetable production: Case study for Antalya region, Turkey. Energy Conv Manag 46 : 655—666.

Dazhong W, Pimental D (1984) Energy flow through an organic agro-ecosystem in China. Agric Ecosyst Environ 11 : 145—160.

Devasenapathy P, Senthilkumar G, Shanmugam PM (2009) Energy management in crop production. Ind J Agron 54 (1) : 80—90.

Ecker D (1995) Corn production in Ohio, 1995. http://ohioline.osu.edu/b472/. Htm Food and Agricultural Organization (FAO). Yearbook of Maize Production FAO, Rome. Italy 1999 45 : 265.

Franzluebbers AJ, Francis CA (1995) Energy output : Input ratio of maize and Sorghum management systems in Eastern Nebraska. Agric Ecosyst Environ 53 : 271—278.

Jayadeva HM, Shetty TKP, Bandi AG, Gowda RC (2010) Water use efficiency, energetics and economics of rice as influenced by crop establishment techniques and sources of nitrogen. Crop Res 39 (1–3) : 14—19.

Kalbande SR, More GR (2008) Assessment of energy requirement for cultivation of *kharif* and *rabi* Sorghum.Karnataka J Agric Sci 21 (3) : 416—420.

Liu Y, Langer V, Høgh-Jensen H, Egelyng H (2010) Life cycle assessment of fossil energy use and greenhouse gas emissions in Chinese pear production. J cleaner Prod 18 : 1423—1430.

Lorzadeh SH, Mahdavidamghani A, Mohammad Yousefi MR (2011) Energy input-output analysis for maize production systems in Shooshtar, Iran. Adv in Environm Biol 5 (11) : 3641—3644.

Mangal MQ, Mahmood Hemat, Llah Habibu Hamayoun, Sayed Rahim Ghafari, Mohammad Naim Jalali (2017) Response of maize varieties under variable planting geometry in Kandahar semi-arid situation. Int J Appl Res 3 (10) : 74—78.

Mohammadi A, Omid M (2010) Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Appl Energy 87 : 191—196.

Morteza Taki, Hassan Ghasemi Mobtaker, Nasim Monjezi (2012) Energy input –output modeling and economical analyze for corn grain production in Iran. Elixir Agric 52 : 11500—11505.

Norwood CA (2001) Dry land corn production in Western Kansas: Effect of hybrid rity, planting date and plant population. Agron J 93 : 540—547.

Ozkan B, Akcaoz H, Fert C (2004) Energy input-output analysis in Turkish agriculture. Renew Energy 29 : 39—51.

Sangeetha C (2013) Effect of crop establishment methods and weed management practices on the productivity of lowland rice and its residual effect on succeeding crop. PhD thesis. TNAU, Coimbatore, Tamil Nadu, India.

Shafique Qadir Memon, Nadeem Amjad, Riaz Ahmed Dayo, Ghulamullah Jarwar (2015) Energy Requirement and Energy Efficiency for Production of Maize Crop. Europ Acad Res 2 (2) : 14609—14614.

Taheri Garav A, Asakereh A, Haghani K (2010) Energy elevation and economic analysis of canola production in Iran a case study : Mazandaran province. Int J Environm Sci 1 (2) : 236—243.

Zeleke A, Alemayehu G, Yihenew GS (2018) Effects of planting density and nitrogen fertilizer rate on yield and yield related traits of maize (*Zea mays* L.) in North Western, Ethiopia. Adv Crop Sci Tech 6: 2.