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EFFECT OF NUTRIENT MANAGEMENT ON ENERGETICS OF LOCAL AND HYBRID VARIETIES OF MAIZE

***SHRUTI KUMARI[1] AND Dr. SHIV PRASHAD SINGH[2]**
[1]*Research Scholar , Department of Botany, Veer Kunwar Singh University, Ara, 802301*
[2]*Retd. Professor and Head, Department of Botany , Veer Kunwar Singh University, Ara, 802301*

Key words:- *Energy statics, calorific value, yield, soil property, hybrid variety , local variety.*

ABSTRACT

Energy efficiency of cereals need to be improved as cereals are the major food grains consumed worldwide. Nutrient management and seed selection will help on improving energy structure in different varieties of maize such as local and hybrid variety. To study the effect of different nutrient level on energy structure of local and hybrid varieties, the NPK based fertilizer and FYM (farm yard manure) was applied on total four main plots, divided in to subplots. Energy per unit area of different plant part was determined at 30-60 DAS, 60-75 DAS and 75 DAS to maturity. Energy productivity, net energy , energy input and energy output was calculated under 100% NPK + FYM application. Calorific value of the different plant part helped in calculating Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) of maize.

1 INTRODUCTION

In crop production increasing energy demands has highlighted the necessity of improving crop variety with nutrient management and genetic modification. Out of all major maize growing countries India comes under top 10 highest maize producers (Negi et al. 2005). Maize has relatively higher per centage of carbohydrate and lipids as it contains 70- 75 per cent starch, 8-10 per cent protein, 4-5 per cent fat, 5-7 per cent crude fiber (Sinha and Sharada, 1992). Various food items such as roti, crackers, popcorn, biscuits and snakes are prepared from maize due to its better nutritional value in the aspect of energetics (Serna et al, 1994; Dhaliwal and Dogra, 2000). The consumption of maize has various diversity as compared to other cereal or energy rich foods. This diversification in the energetics enhances the development of maize products and helps to improve the energetic attribute of the cereal like maize. Apart from food industry , oil seeds are primarily used for oil extraction and the residue after the extraction is rich in protein and commonly used as animal feed. The cereal based foods, being rich in protein meal can be served as supplement to improve the nutritional quality of food. Various programs have be run now a days by the government to promote the maze based cropping system as high yielding variety is maize is used to promote the cultivation and growth of the maize. Quality protein maize (QPM) has been adapted by developing countries to improve the protein quality of maize and reduce protein energy malnutrition. Quality protein maize (QPM) shows higher lysine 6- 13.5 g/ 100 g protein and tryptophan 0.9 – 1.3 g/ 100 g of protein content than regular maize . For the development of maize based food product India has worked considerably in the field of specially corn such as sweet corn, popcorn, high oil corn, waxy corn, baby corn, quality protein maize , green eared corn and fodder maize (Table 1).

Types of corn	Varieties developed and released in India
Sweet corn	Priya sweet corn , Madhuri sweet corn
Pop corn	Amber pop corn, VL pop corn
Baby corn	CO1, early composite, VL 64, PEHM-1, Him 123 , PEHM-2
Quality protein maize	Shakti-1, Shaktiman-1, Shaktiman-2
Green eared corn	Harsha, Ashwini, Rohini, Megha and Varun
High oil corn	Histarch, Deccan 103, Deccan 105, Trishulata, Ganga, Sheetal, Paras
Fodder corn	j-1006, PFM-66, African tall

Table 1 variety of corn in India (source; Director of maize research).

Maize is predominantly cultivated as a kharif crop in western region of Bihar, Eastern Uttar Pradesh, Madhya Pradesh, Punjab, Maharashtra, Karnataka and some regions of Rajasthan. Maize production estimated at over 43 million tons in 2024-25 in India. However the average productivity is not that satisfactory as compared to its productivity worldwide as India ranks 6th globally in maize production. The productivity is affected by water stress, poor recycling of crop residue, inappropriate use of fertilizer and manure and nitrogen and phosphorus availability in the soil (Rego *et al*. 2003), deficiency of Sulphur , zinc and boron also led to poor growth pattern and low productivity (Sahrawat *et al*. 2007). Different maize varieties show different response to nutrient treatment at different stages of life cycle. Hybrid maize show more response to nutrients as compared to local varieties and show better growth and yield after application of inorganic fertilizer and manure (Sarkar *et al*. 2000). Organic manure solely cannot compensate the nutrient requirements of plant (Chaudhary *et al*. 2004) but it improves the soil structure that supports plant growth during vegetative stage. Maize is one of the highest energy producing foods as 100 gram of grains has average 365 Kcal energy. Maize grains are rich in highly digestible starch (carbohydrate) 70- 85%, protein 10-15% and oil 2-6% including some minerals like potassium and magnesium. Intensive use of energy has brought new challenges for agriculture, public health and ecological functions. To lower the environmental issues caused by modern agricultural practices energy use efficiency should be increased. The resource allocation improvement , improves the energy output and input at crop level (Pal et al. 1985 ; Dazhong, 1988).The energy output can be increased by increasing RDF(Recommended Dose of Fertilizer) from 100% to 125% NPK based fertilizer along with FYM. Maize is primary resource for ethanol production and gasification of cob produces biogas and electricity. Maize being primarily C_4 plants use water more efficiently than C_3 plants, that makes it more efficient crop for less irrigated or rainfed areas. Improper nutrient management lead to low nutrient use efficiency and cause environmental pollution (Bijay-Singh et al. 2015). Therefore, the present study was carried out to evaluate the energy statics of hybrid and local varieties of maize under different levels of nutrient management.

2 MATERIALS AND METHODS

2.1 Site of experiment

The experiment was conducted at local farm near Veer Kunwar Singh University in year 2024 and 2025 on alluvial soil of Ara , Bhojpur, Bihar, India (25.55^{o} N latitude and 84.66^{o} E longitude), the pH recorded during cropping season (2024-25) was 6.9 and 7.5 respectively. 80 to 85% of the total rainfall occurs as monsoon rainfall, rest happens as pre monsoon shower and winter rainfall. The chemical and physical properties of the soil of experimental site was determined. The soil of the experimental site at 0-20cm of depth was rich in sand , silt and clay with percentage distribution of 55.6%, 20.3%, and 22.4%. Soil was having low organic carbon 0.2 in first year and 0.7 in second year determined by Walkley and Black’s rapid titration method (Jackson 1967). The available N (Alkaline Potassium Perrmagnate method ; Subbiah and Asija 1956) ,P (0.5 N sodium bicarbonate extraction method ; Olsen *et al* 1954),K (IN Ammonium acetate extractable method ; Muhr 1965) ,Zn (DTPA extraction method ; Lindsay and Norvell 1978), S (Calcium Chloride “$CaCl_2$”extraction method ;Chesnin and Chung H. Yien 1951) and B (Hot water extraction method ; Berger and Truog 1939) was also determined . However N, P, and Zn was found low in the alluvial soil of the experimental site for both the years, rest K, B and S was found medium (fig 1)

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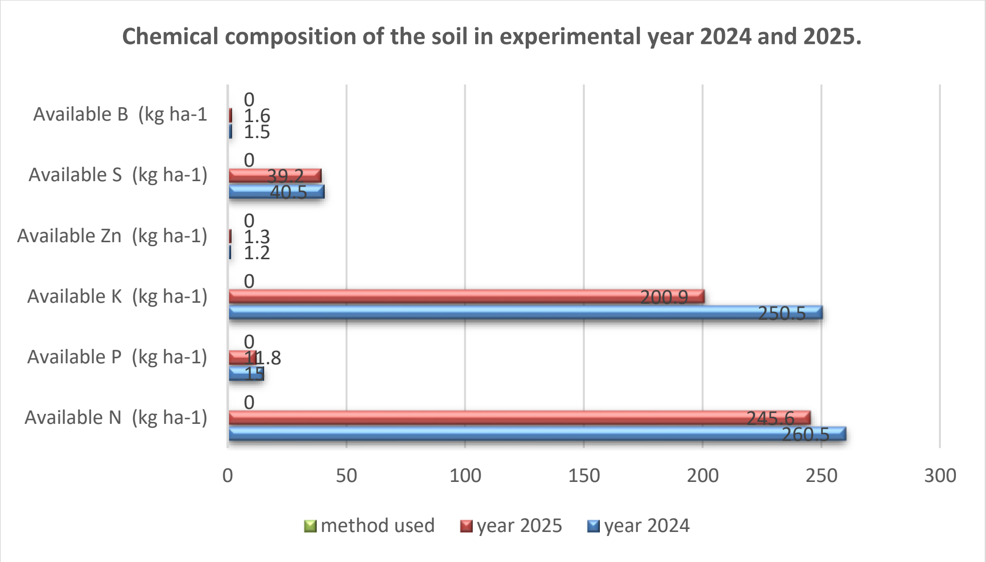
Fig 1 : Chemical composition of alluvial soil in year 2024 and 2025.



2.2 **Seed selection and growth attribute**

Maize seed selected for the experiment was checked on the parameter of physical and physiological characteristics for healthy and uniform grain. The sample was carefully examined to ensure uniform size, shape and colour, however the damaged and diseased seeds were eliminated and only high viability seeds were chosen for sowing. The seed viability was checked under controlled laboratory conditions using standard germination test method. Moist germination paper was used to place the sample grain and incubated at an optimum temperature of 25^0C , ±2-3^0C . After recording germination percentage in 6-7 days , the viable seeds with more than 85% of germination potential was used. To prevent the seeds from any kind of fungal diseases the seeds were treated with Carbendazim the fungicide at the rate of 2 – 3 gram per kg of seed also the seed was treated with few biofertilizers such as Azotobacter to enhance nitrogen fixation. Maize seed taken for the experiment was of four varieties and total 20 kg (energy equivalent 294.01 MJ) of seed was taken . Two local (Desi Makka and Sathi Makka) and two hybrid varieties (Pusa HM-4 and Shaktiman-1). The local varieties showed early maturation and low input but hybrid varieties were stress tolerant and rich in some essential amino acids. The growth parameter was recorded right from germination to different intervals to evaluate the performance of the crop under different treatments . The germination percentage was calculated by dividing the number of germinated seeds within the specific period after sowing with total number of seeds sown multiplied by 100. A random selection of five plants was done from the experimental site from each plot for the recording of observation. Plant height was measured first from the base of the plant to the tip of the tassel using measuring scale at different growth stages such as 30 DAS, 60 DAS, 75 DAS and at maturity. The average hight was recorded in centimetres. Number of leaves per plant was counted manually at different growth stages, and to assess the photosynthetic surface the leaf area index (LAI) was calculated . The standard formula used for calculating the leaf area index was the division product of leaf area per plant to ground area occupied by the plant. Leaf area index was important to calculate as the photosynthetic rate determination was important for the calculation of the energetic content because the stored nutrient after photosynthesis informed about the total energetic attribute.

Leaf area index (LIA) = Leaf area per plant / Ground area occupied by the plant

The plants were uprooted at different growth stages to calculate the dry matter accumulation, by washing and separating after the wash. The oven dried sample at 65^0C was taken for the consideration. The growth rate was calculated with the formula to determine the increase in biomass in defined interval of time. The efficiency of plant growth over time was recorded by this parameter. The

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data collected by the observations were subjected to statistical analysis using analysis of variance (ANOVA) , very useful for random data interpretation.

Crop growth rate (CGR) = $W_2 - W_1 / T_2 - T_1$

2.3 Energy structure attribute

Both input and output energy was calculated into energy unit that is mega joules per hectare, MJ ha^{-1} that is a standard energy equivalent. Total energy input in MJ ha^{-1} was equals to product of quantity of input and energy equivalent, so all individual energy inputs were summed to obtain the total energy input in maize cultivation. The energy inputs were renewable source of energy such as human labour, seed and farm yard manure and non- renewable source of energy such as diesel, electricity, fertilizers, pesticides and machinery. The direct energy input was human labour ≈ 1.97 MJ/ hour, diesel (fuel ≈ 56.32 MJ/Litre),electricity ≈11.96 MJ/kWh , and the indirect energy input used was seed, fertilizers (N ≈ 60.5 MJ/kg, P ≈ 10.9 MJ/kg , and K ≈ 6.8 MJ/kg), pesticide 120-320 MJ/ kg and machinery. For energy output calculation grain and straw yield was important as the total energy output in , MJ ha^{-1} was calculated as the sum total of products of grain yield and energy equivalent and straw yield and energy equivalent. Total energy output recorded was from grain yield ≈ 14.8 MJ/ kg and stover ≈ 12.8 MJ/kg, the formula used for calculating energy input and energy output have been listed below.

Total Energy Input = ∑ (Input quantity × Energy equivalent)

Energy Output = (Grain yield × 14.8) + (Stover yield × 12.8)

To determine the energy indices it was important to calculate energy use efficiency (energy ratio) that is total energy output divided by total energy input, specific energy that is total energy input divided by grain yield (MJ kg^{-1}) , energy productivity that is grain yield divided by total energy input (kg MJ^{-1}) , net energy gain that is total energy output subtracted by total energy input and energy profitability that is net energy divided by total energy input. The energy structure determination was important and it was analysed by calculating percentage contribution of each input to the total energy consumption. The percentage contribution (%) was calculated when energy of individual input was divided by total energy input and the resultant value was multiplate by 100 to calculate percentage.

Percentage contribution (%) = (Energy of individual input/ Total energy input)× 100

2.3 Method of data analysis

The collected data was analysed using different tools to determine variability and significance of different energy components. Mean value , and ratio along with percentage were calculated and represented graphically such as bar cart form to illustrate the total energy distribution and total energy structure. Different nutrient level was applied to the experimental crop , for two experimental year 2024 and 2025. The data was collected primarily regarding inputs used in the cultivation of maize crop on the experimental site through field observation. Farmer interview was done to have a check on experimental record. The inputs were categorised in to direct energy sources and indirect energy sources. The direct energy sources included human labour, diesel fuel, electricity and water for irrigation, however the indirect energy input included seeds, fertilizers such as nitrogen, phosphorous, potassium and other micro and macro nutrients along with FYM (farm yard manure),machinery and pesticide. All the quantities of the materials being used as the energy input sources per hectare were recorded carefully. Kharif maize was grown in split plot design (SPD) in alluvial soil of the experimental site. The local variety was treated with 100% NPK along with FYM in year 2024 and both local and hybrid varieties were treated with 100% NPK and FYM for the second year experiment 2025. The calorific values and slandered deviation was recorded for both the years of different plant parts such as grain, stem, root and leaf on 30 DAS, 60 DAS , 75 DAS and at maturity. Pooled mean of both calorific value and standard deviation was calculated for two years for calculating average energy investment and energy gain. The output data was also measured at harvest such as grain yield and straw yield to measure overall energy accumulation.

Pooled Mean = (Result of experiment in year 2024 + Result of experiment in year 2025) / 2

3 RESULTS AND DISCUSSION

3.1 Energy status of local and hybrid varieties

The evaluation of energy status between local and hybrid varieties of maize informs about the differences between energy input, energy output and overall energy efficiency , however the hybrid varieties exhibited higher productivity and energy output, but the local varieties showed relatively lower energy input requirement. As compared to local varieties, the hybrid varieties required higher energy input in the form of irrigation and seed selection. The chemical fertilizer contributed maximum in in total energy input, accounting for about 50-55% in hybrid varieties that was Pusa HM-4 and Shaktiman-1 and 40-45 % in local varieties that was Desi Makka and Sathi Makka. Nitrogen based fertilizer was the major contributor of due to its high energy equivalent. Higher energy demand also required more water for irrigation, human labour and machinery as an energy input source, however the local varieties (Desi Makka and Sathi Makka) were enough to grow using traditional practices that required lesser labour as compared to hybrid varieties (Pusa HM-4 and Shaktiman-1) . Net energy input , net energy output and productivity of the crop was determined under nutrient and non-nutrient treatment to local and hybrid varieties used for the experiment. The data recorded was expressed in mega joule per hectare (MJ ha^{-1}). Application of 100% NPK + FYM to the local varieties increased the energy output and input in year 2024 , however application on only FYM to the hybrid varieties showed average energy statics. For second year experiment in 2025 the application of 100% NPK and FYM was done for all four varieties , two local varieties (Desi Makka and Sathi Makka) and two hybrid varieties (Pusa HM-4 and Shaktiman-1) and the hybrid varieties showed maximum growth attribute and accumulation of energy in nutrient form . Ajit Kaur Bhatia and Rajesh *et al.* (2010) ; stated that maize grown with proper management practices show enhanced protein accumulation. Distribution of energy among the different plant parts varied according to energy input in complete growth of the kharif maize. Leith (1968) stated that high energy output is gained during growth stage , the use of fertilizer increases to overall growth that resultantly increases energy output (Kumar 2011 and Golla *et al*. 2020). Energy output was calculated based on grain and straw yield, that was significantly higher for hybrid variety than that of the local variety. The higher energy output for the hybrid varieties can be attributed to their superior genetic potential and better nutrient utilization that gave higher biomass production oner entire growth phase. The total grin yield contributed to the major portion of total output energy , followed by straw. The ratio of energy output to energy input is defined as energy use efficiency (EUE) , that indicated the overall system performance . Local varieties (Desi Makka and Sathi Makka) exhibited lower energy use efficiency (EUE) that was 4.5 - 6 as compared to the hybrid varieties (Pusa HM-4 and Shaktiman-1) ranging from 6 – 7.5. The major potential of the hybrid grains were that , they were able to convert higher energy inputs in greater energy outputs.

The specific energy indicated the amount of energy required to produce a unit of grain yield was lower in hybrid varieties (Pusa HM-4 and Shaktiman-1) that was 2.5 – 3 MJ kg^{-1} as compared to local varieties (Desi Makka and Sathi Makka) that was 3.0 – 3.5 MJ kg^{-1} . The inverse of specific energy was energy productivity and that was higher in hybrid varieties as compared to the local varieties. That suggested , hybrid varieties are more efficient in utilizing energy inputs to produce yield. The response to fertilizer and higher photosynthesis rate was the major region behind higher productivity. The finding of the experiment clearly indicated that hybrid maize varieties (Pusa HM-4 and Shaktiman-1) outperformed local varieties (Desi Makka and Sathi Makka) in terms of energy output, energy use efficiency and the net energy return and this consistency was reported due to better genetic improvement and better agronomic management. Local varieties (Desi Makka and Sathi Makka) having lower productivity required lower investment of the energy input and was also cost effective and sustainable. They were suitable for rainfed areas and low input energy farming availability areas where resources are limited. So, the choice between local varieties and the hybrid varieties should therefore depend on the availability of resources , environmental and economic conditions and sustainability goals.

Fig Energy per unit area of root

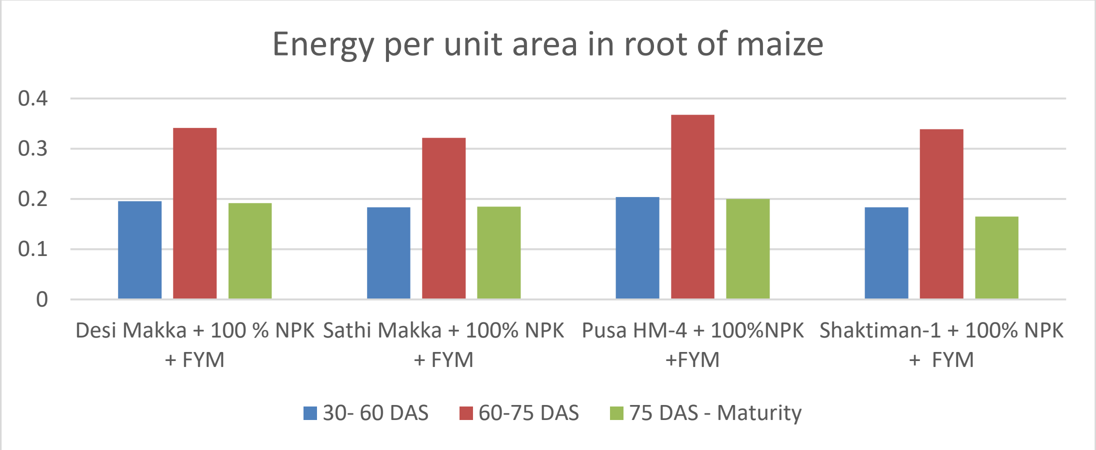

Fig Energy per unit area of shoot

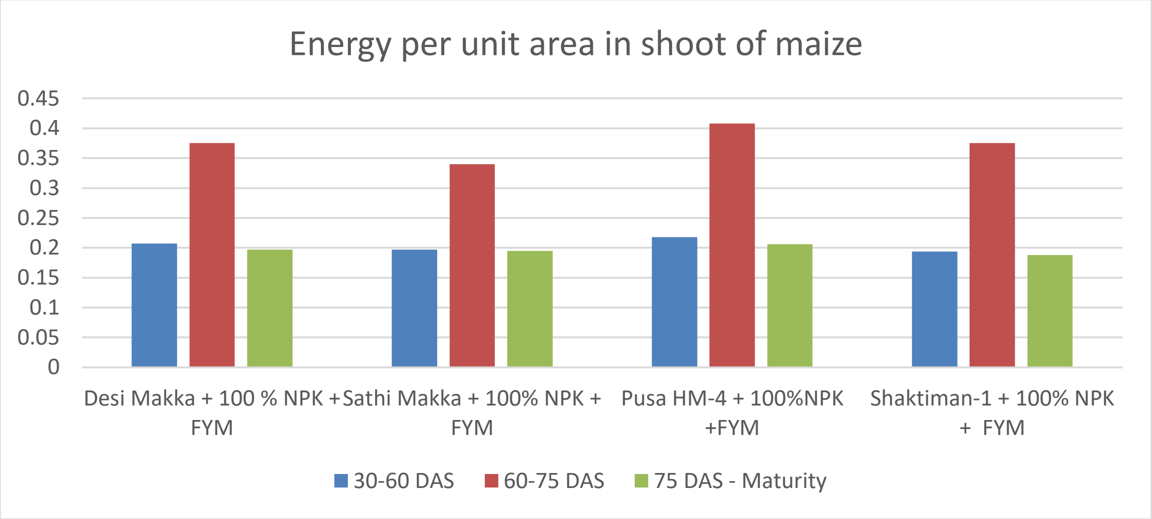

Fig Energy per unit area of leaf

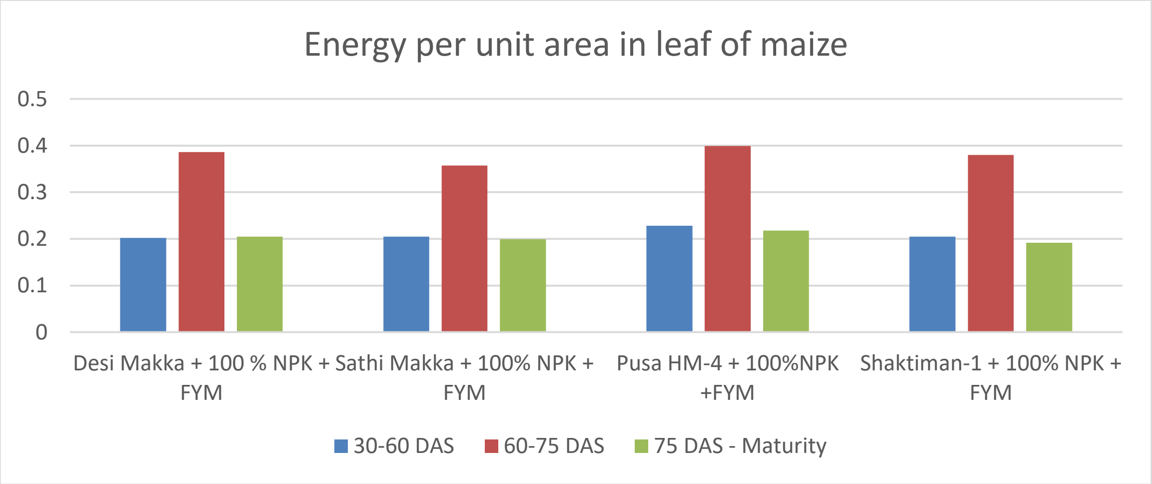

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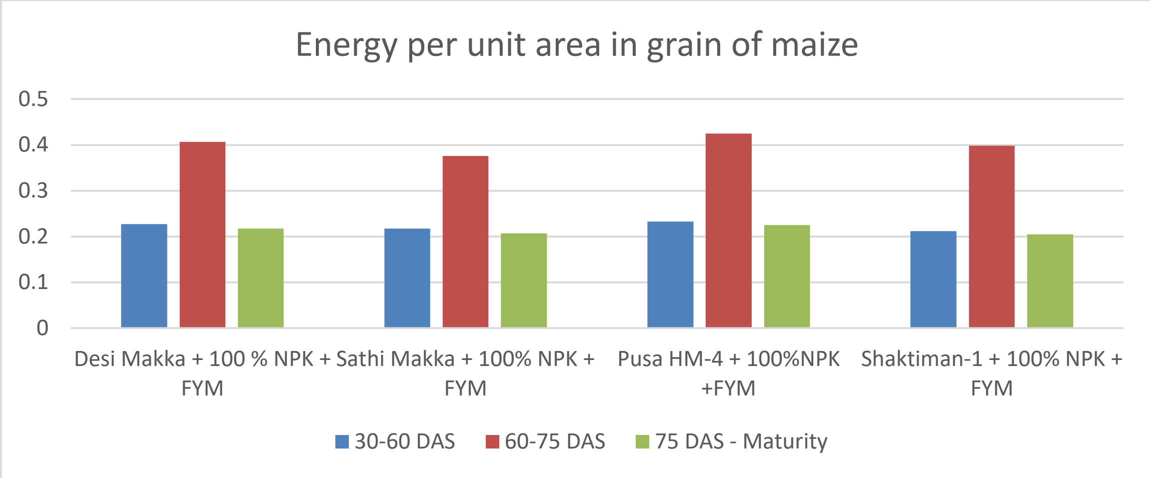
Fig Energy per unit area of grain



3.2 Calorific value and standard deviation calculation

Calorific value of different plant part was also calculated to understand the energy potential, to determine the energy stored in total productivity of the plant. Due to difference in the biochemical composition and genetic potential, the calorific value of the maize grain and straw varied between local varieties (Desi Makka and Sathi Makka) and hybrid varieties (Pusa HM-4 and Shaktiman-1) . Calorific value was determined by calculating the amount of heat energy released when 1 kg of dry matter is completely burnt . Once interpretation of variability was done a consistent, in contrast the hybrid varieties showed relatively lower standard deviation compared to local varieties that indicated greater uniformity in their potential of functioning and reliable calorific value was obtained by measuring low standard deviation value. This consistent biochemical composition was due to better genetic makeup and more uniformity in the sample seed. However , local varieties showed higher variability due to more adaptability and greater diversity , that lead to significant fluctuation in energy content . The coefficient of variation (CV) was found to be less than 5 per cent in hybrid varieties and approx. 6 per cent in local varieties , same calculated as the ratio of standard deviation to mean expressed as percentage . The difference between grain and straw calorific value was slightly more pronounced in hybrid varieties (Pusa HM-4 and Shaktiman-1) that indicated better and greater portioning of starch and other energy rich components in the grains. The formula used for calorific value was;

Calorific value (MJ kg^{-1}) = Energy output (MJ kg^{-1}) / Biomass yield (KG ha^{-1})

The highest calorific value was recorded in grain because the grain was having higher accumulation of starch with a range between 18.26 MJ kg^{-1} to 18.96 MJ kg^{-1} with an standard deviation of 0.35. Among all the different parts of the plant the minimum calorific value and standard deviation recorded was for root 15.70 MJ kg^{-1}.

$$SD = \sqrt{\sum(x_{I} - \bar{x})^2 / n-1}$$

Where :-

- X_i = Observation
- $\bar{X}$ = mean
- n = no of replication
- $\sum$ = summation
- SD = standard deviation

First the mean was calculated from tress replications,

$$\bar{X} = \frac{18.45 + 18.80 + 19.15}{} = 56.40/3 = 18.80$$

3

$\bar{X}$ = 18.80, now the found mean value is subtracted from the observations, and square of the differences are taken,

1. 18.80 – 18.45 = + 0.35 ; Now square of - 0.35 = 0.1225
2. 18.80 – 18.80 = 0.00 ; Now square of 0.00 = 0.0000
3. 18.80 - 18.15 = -0.35 ; Now square of +0.35 = 0.1225

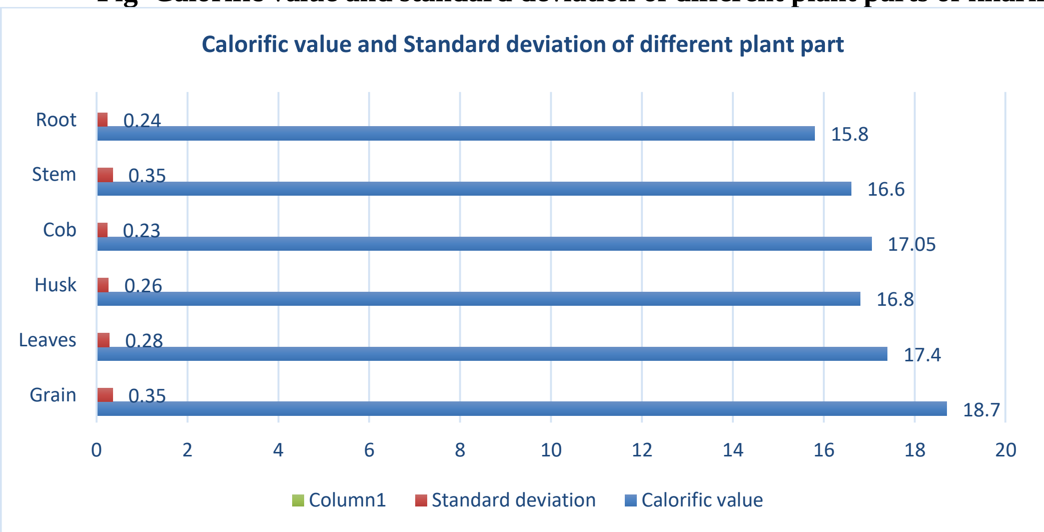
Now sum of square deviations taken ; $\sum (x_i - \bar{x})^2$ = 0.245 ; and divided by (n-1) ; 0.245 / 2 = 0.1225Now for Standard Deviation square root of the data is taken;

SD = $\sqrt{0.1225}$ = 0.35

SO, the final Grain calorific value was 18.80 , ± 0.35 MJ kg^{-1} and resultantly 1 kg of experimental dry maize grain produced 18.80 megajoules of energy .

The comparative analysis of calorific values between local and local maize varieties highlighted the superior performance of hybrid varieties (Pusa HM-4 and Shaktiman-1) over local varieties (Desi Makka and Sathi Makka) in terms of energy content. When the total yield was taken for consideration the higher calorific value of the hybrid varieties (Pusa HM-4 and Shaktiman-1) contributed the greater total energy output, however the difference of calorific values between two sample hybrid varieties (Pusa HM-4 and Shaktiman-1) were not that variable as most of the superiority was seen for Pusa HM-4 than that of for Shaktiman-1 for hybrid varieties. So, the local varieties are commonly used in low input farming system due to their low energy use potential. The application of 100% NPK along with farm yard manure enhanced the calorific value of the local variety as well. For the determination of total energy output in crop production system the calorific value played very crucial role, because a small variation in calorific value may led to significant influence on overall energy calculation when multiplied by the yield. For reliable energy analysis accurate estimation and low variability are essential . The higher energy content in the maize grain was due to accumulation of starch and energy rich nutrients. The uniformity and better genetic make up of the hybrid varieties (Pusa HM-4 and Shaktiman-1) contributed to both calorific value and variability . However the role environmental factors such as soil quality, rainfall, relative humidity, and sun shine length along with soil fertility and crop management practice cannot be ignored. As a resultant the study demonstrated that maize grain posses higher calorific value than straw and the hybrid varieties (Pusa HM-4 and Shaktiman-1) posses slightly superior energy characteristics as compared to local varieties (Desi Makka and Sathi Makka)

Fig Calorific value and standard deviation of different plant parts of kharif maize.



Maximum calorific value was recorded for grains as the accumulation of starch is maximum in the grains and the minimum recorded calorific value was for root of the plant . The dried grain was rich in all accumulated nutrients such as starch, protein and oil along with some other macro and micro nutrients. The other parts of the plant such as stem, husk, cob leaves and root were having relatively lower accumulation of energy in the form of food. Leaf and stem had optimum energy accumulation but had slight decrease in the nutrient accumulation at maturity due to less or not photosynthesis . The root on the other hand was not having any specific nutrient accumulation in case of both local and hybrid variety so the overall energy contribution from the root of the plant was not that significant. As the use of the NPK based fertilizer along with the farm yard manure (FYM) enhanced the rate of photosynthesis and the mobilization of the formed food in the plant was also recorded slightly higher after the application of fertilizer. As a result it was recorded that increasing the amount of fertilizer increased the overall growth of the experimental crop also the energy content of the plant in the form of nutrients such as starch, protein, oil and other micro and macronutrients got increased . The NPK based fertilizers along with farm yard manure (FYM) increased the plant growth once the treatment was increased from 75 per cent to 100 percent and then from 100 per cent to 125 per cent. The finding highlighted the importance of integrating calorific value and statistical parameters in energy analysis to find out the interpretations for crop production system. Energy was calculated using same formula ;

Energy output (MJ m^{-2}) = Biomass yield (kg m^{-2}) × Calorific value (MJ kg^{-1})

4 CONCLUSION

The major conclusion drawn from the study of the nutrient management on the energetics of local and hybrid maize varieties provided comprehensive insights into the relationship between input use , crop performance and energy efficiency. Fertilizers used specially nitrogen , potassium and phosphorous contributes major growth attribute the overall plants energetic content in the form of food . Increasing the level of fertilizers from 75 % to 125 % increased the input energy for both local varieties (Desi Makka and Sathi Makka) and the hybrid varieties (Pusa HM-4 and Shaktiman-1) However this increase in input energy was observed as rise in crop productivity that indicated a positive role of nutrients specially the fertilizers in promoting and enhancing the energy output. The net energy return along with energy output and energy use efficiency was found to be superior for hybrid varieties as compared to the local varieties taken for the experiment. The hybrid varieties (Pusa HM-4 and Shaktiman-1) had a greater ability to convert applied nutrient and other inputs in to biomass and higher grain yield. However local maize varieties exhibited lower energy input due to less efficiency and uniformity . In fact the local varieties (Desi Makka and Sathi Makka) maintained a good balance between input and output energy under low input conditions also. This suggested that for average energy requirements the local varieties are better to grow with less resource availability and smaller farming practices. The key energy parameters such as specific energy, energy productivity and net energy gain showed significant effect on crop growth once different nutrient level was used in the experimental site. However beyond the optimum level , the rate of increase in energy output was not proportional to the increase in input energy, that suggested about the return may be decreased by applying higher nutrients in the form of fertilizer. The energy analysis is important in the study of crop production. A better comprehensive understanding can be drawn by evaluating both input energy and output energy. The study demonstrate that nutrient management is the key factor for energy efficiency in maize production. Hybrid varieties (Pusa HM-4 and Shaktiman-1) after getting combined with balanced and optimal nutrient application demonstrate highest potential for maximising energy output and overall system efficiency, whereas local varieties (Desi Makka and Sathi Makka) showed higher potential for sustainable agriculture due to their lower energy requirements and better adaptability along with resilience. Different varieties of maize grains have different growth potential . Hybrid varieties (Pusa HM-4 and Shaktiman-1) showed maximum growth potential and more accumulation of energy than that of local varieties (Desi Makka and Sathi Makka) . Application of 100% NPK + FYM enhanced the growth of the crop even more and energy accumulation in the form of nutrients enhanced . More starch, protein , oil and some essential minerals were found in grains of hybrid maize than traditionally used local maize seeds. So, it is recommended that farmers adopt better nutrient management for specific and selected seed varieties and available resources. To achieve a balance between productivity and energy efficiency with sustainability is very important for profit based maize cropping system for long term output. The future research should focus on improved variety development with better genetic modification and better nutrient management to enhance energy efficiency while minimising environmental impact, that contribute to sustainable agriculture.

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