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Research Article

Effect of Intercropping, Elevation and Nitrogen Dose on Performance of Maize-mungbean Cropping Systems

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Abstract: Monocropping of traditionally grown maize (*Zea mays* L.) on diverse elevations with inappropriate fertilizer dosage is leading to low land productivity and staple food insecurity in the mountainous areas. Therefore, a study was conducted to investigate the impact of replacing the traditionally grown maize variety with an improved variety and influence of elevation, intercropping and nitrogen (N) fertilizer levels on growth and yield of maize and mungbean (*Vigna radiata* L.) grown in different sole and mixed cropping systems. Field experiments were carried out using 3×3×3 factorial combination of three elevations (i.e., 1500 m, 1800 m & 2200 m above mean sea level), three cropping systems: i.e., sole maize (conventional and introduced cultivars) and intercropping (i.e., maize + mungbean), three N levels (i.e., 28, 56, 113 kg N ha^{-1}) organized in a randomized complete block design layout. Plant height of maize and grain yield of both maize and mungbean were recorded after harvesting. Land Equivalent Ratio (LER) and nutritional parameters (i.e., carbohydrates, protein, fat and digestible energy) in harvested grains were computed. Higher ($P \leq 0.5$) growth, yield and nutritional parameters were observed at elevation of 1500 m followed by 1800 m and 2200 m. Growth and yield components of introduced maize were higher compared to traditionally grown sole maize. Nutritional parameters ($P \leq 0.5$) were greater for intercropping compared to sole cropping of maize. Despite a substantial reduction ($P \leq 0.5$) in growth and yield components of mungbean in intercropped situation, its contribution to overall production led to increased LER (1.9) of the intercropping system over sole cropping of maize.

Keywords: Carbohydrate**,** digestible energy, fat, intercropping, land equivalent ratio, maize, mungbean, protein

1. INTRODUCTION

Crop diversity through intercropping increases land productivity and ensures sustainability of production. Intensive and extensive cultivation of monocultures is an inherent threat to agro-biodiversity and soil resource [1]. This is owing to fact that single cropping patterns give tough time to a variety of biological populations through limiting their access to diverse opportunities for survival in such type of ecosystems [2]. Sequentially grown exhaustive crops (like cereals) over-exploit soil resource and reduce sustainability potential of futuristic agro-ecosystems in different agro-ecological zones. Thus, establishing or expediting flow of natural dynamic resources among soil, plant and atmospheric systems helps in ensuring sustainability of underlying agro-ecosystems [3].

When grown in intercropping, legume plants bring multiple benefits. In addition to serving as staple food (like pulses), legumes help diversify the farm produce for benefits in terms of income and in case of major crop (like cereals) reduce the chances of failure due to natural calamities [4]. Additionally, due to the presence of root nodules, legumes add nitrogen (N) in the soil profile through biological fixation. Thus, to exploit benefits of legumes, its inclusion in cropping

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pattern is imperative [5]. Moreover, consumption of legume seeds provides sugars and protein and increases total contents of digestible energy in diet.

Maize (*Zea mays* L.) is grown in wider inter row spacing to reduce intra-specific competition and for greater solar radiation penetration to the lower leaves especially during its peak vegetative growth stages [6, 7]. It has slow growth at initial growth stages while leaving inter-row spacing uncovered that is usually exposed to evaporative losses of soil water content, soil particle displacement (erosion) due to irrigation water flows and also serves as a potential resource for germination of various kinds of undesirable plants or weeds [4]. Establishment of legume cover at inter-row spacing of maize during early growth stages helps protect soil moisture loss, reduced weed germination and soil erosion vulnerability especially on sloppy surfaces [8].

Use of fertilizers for harvesting greater yields has had increased drastically since the Second World War [9, 10]. In particular, use of N fertilizers accounts for 30-40 % of total crop productivity [11]. However, application of excessive N fertilizer dosage to crop may result in accumulation of nitrate in the cropped soils and leaching to ground water, resulting in environmental and health issues [9, 10, 12]. In intercropping, legumes compete strongly with maize for N [13] but its growth may be reduced significantly due to competition from maize for moisture, nutrients and sunshine [14].

Plant growth and development are dependent on climatic conditions and climate of any location is partially linked with elevation. These conditions vary with change of elevation, i.e., air temperature decreases with increasing altitude [15]. In mountainous areas of the world, elevation changes from place to place and, therefore, influences crops and cropping systems.

Intercropping is an appropriate approach for small farmers to adjust more than two crops in the same spatial and temporal dimensions [7, 16, 17]. Multiple benefits of intercropping have been highlighted by different researchers; especially the higher productivity of cereal-legume intercropping has been indicated compared to its monocropping [18, 19]. Post-harvest analysis of soil indicated increased fertility levels of land under cereal-legume associations [20]. Forage yield of maize was reduced by 57 % in intercropping with lablab compared to its sole crop [21]. In contrast, grain yield of maize was improved by 17-22 % and 15-20 % when intercropped with soybean and black gram, respectively, compared to sole cropping [22]. Land equivalent ratio (LER) was increased by 43 % for maize-soybean intercropping compared to sole cropping. In mountainous areas having agricultural land with diverse elevations are cultivated with monocropping of traditionally grown maize variety (cv. *Pahari*) and farmers are experiencing low land productivity and shortage of staple food. Therefore, this study was conducted to assess performance of a new variety of maize (cv. Azam) as sole and in intercropping with mungbean (*Vigna radiate* L.) at different elevations on the basis of growth, yield and total digestible energy productivity.

2. MATERIALS AND METHODS

2.1 Experimental Sites and Climatic Conditions

Research experiments were performed in summer season at three different locations, namely Danyure (Gilgit), Gitch (Ghizer) and Thole (Hunza), having elevations 1500 m (135.9202^{o} N, 74.3080^{o} E), 1800 m (361025° N, 73.4600° E) and 2200 m (36.3167^{o} N, 74.6500^{o} E), average temperature 16, 14 and 10 ^{o}C in Gilgit-Baltistan region of Pakistan. The locations have different climatic conditions owing to their different altitudes from mean sea level (MSL) (Fig.1).

2.2 Soil Analysis

Soil sampling of the experimental sites (elevations) and laboratory analyses were carried out by following procedures described by Carter and Gregorich [23]. Soil samples were collected from a depth of 0–30 cm before land preparation at beginning of experimentation (June 24, 2015; June 26, 2016; and July 01, 2015). The samples were dried under laboratory conditions (25 ^{o}C) followed by grinding and sieving using a sieve of

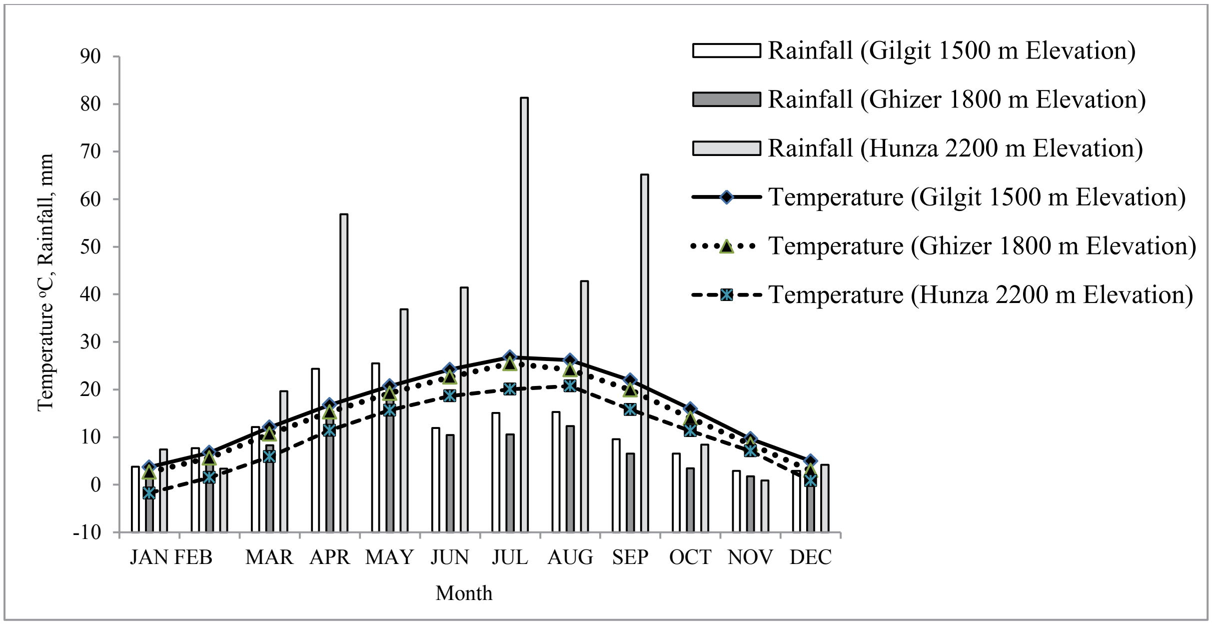

Fig. 1 Average temperature and rainfall in study areas during the year.

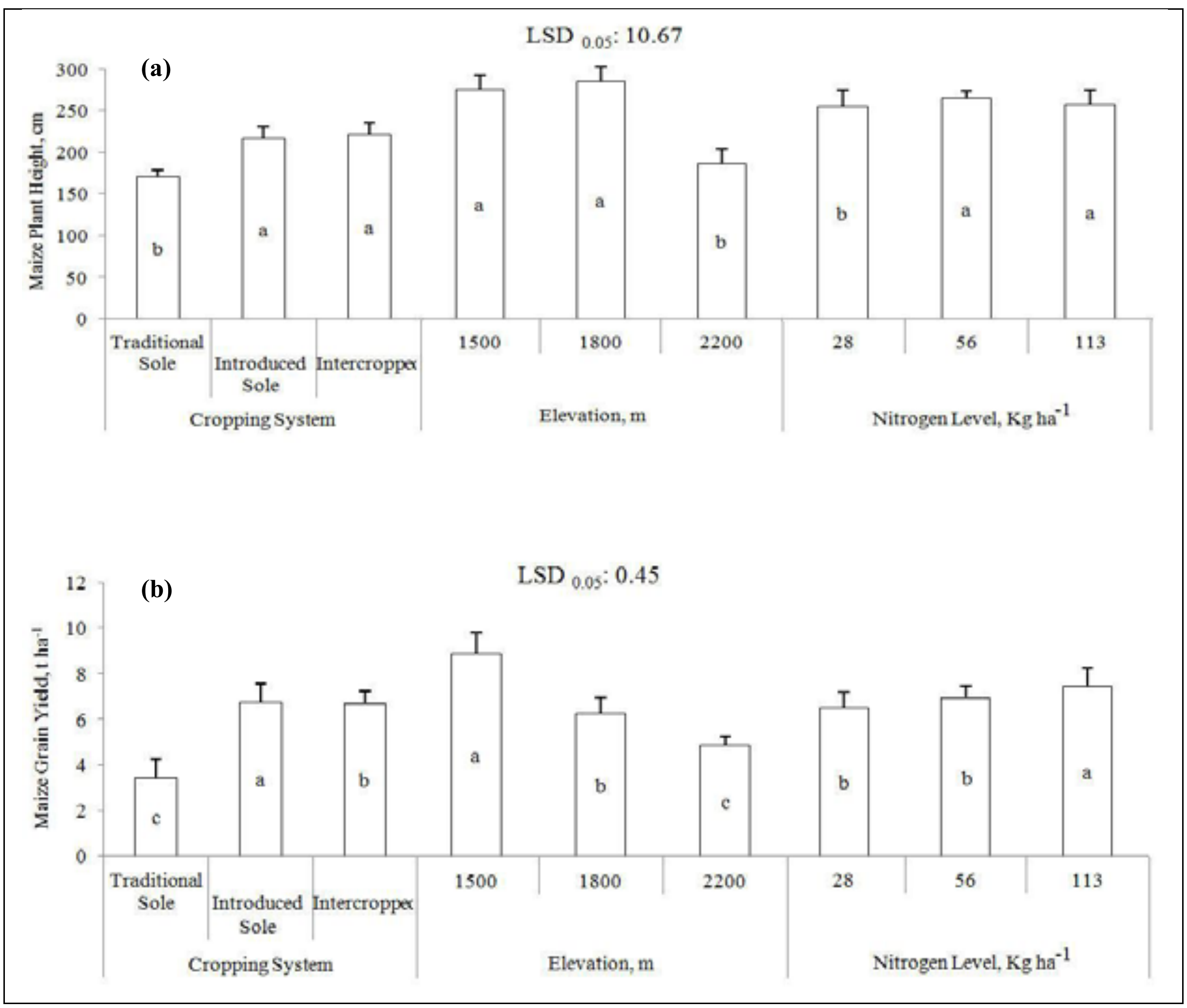

Fig. 2 Effect of cropping system, elevation and nitrogen level on: (a) plant height; and (b) grain yield of maize.

Table 1. Soil properties of experimental sites.

Parameter	Danyure, Gilgit (1500 m elevation)	Gitch, Ghizer (1800 m elevation)	Thole, Hunza (2200 m elevation)
pH	6.5	6.3	6.1
EC (dSm^{-1})	0.30	0.28	0.25
Sand (%)	55	63	60
Silt (%)	15	19	22
Clay (%)	30	18	18
Textural Class	Sandy clay loam	Sandy loam	Sandy loam
Soil Order	Alfisols	Alfisols	Inceptisols

pore size 2 mm. The pH and electrical conductivity (EC) of soil samples were determined using pH and EC meters, respectively. Texture analysis of soil samples was carried in laboratory. Average value of each soil parameter, i.e., pH, EC, sand, silt, clay, soil textural class, soil type, is presented in Table 1.

2.3 Experimental Treatments

Treatments for the field experiments were: three elevations (1500, 1800 and 2200 m), three cropping systems (sole cropping of traditionally grown maize, sole cropping of introduced maize and intercropping of maize + mungbean) and three N levels (28, 56, 113 kg N ha^{-1}). The treatments were organized in factorial ($3 \times 3 \times 3$) combination using layout of Randomized Complete Block Design (RCBD) with three replications. At each elevation, size of each plot was maintained as 6.0 m × 4.0 m. Plots within each replication were apart by one meter vacant area and replications were apart by two meter vacant area. Plant density for maize was maintained as 1×10^5 plants ha^{-1} while for mungbean was adopted as 2×10^5 plants ha^{-1}. Said densities were managed by maintaining inter-row spacing of 50 cm for both maize and mungbean whereas intra-row spacing of 20 cm for maize while 10 cm for mungbean (8 rows per plot for both crops).

2.4 Experimental Management

Land at experimental locations was prepared by means of disc harrow and a cultivator, and leveled using planker behind tractor. Recommended varieties of maize [Azam (introduced) and Pahari (traditional)] and mungbean (NM– 2006) were used. Simultaneous sowing of crops in prepared plots was done on 27th June, 2015 at 1500 m, on 29th June at 1800 m and on 5th July 2015 at 2200 m elevations. Experimental plots were irrigated weekly during the growing season following the germination. Nitrogenous fertilizers were applied according to the treatment level in two splits (i.e., 50% as basal dose and 50% at booting stage of maize) whereas recommended dose of phosphorus (P) (@ 80 kg P_2O_5 ha^{-1}) was applied entirely as basal dose at the time of sowing for both intercropping and sole cropping treatments of maize and mungbean using Nitrophos as the P source [24]. Thinning to optimum plant density and weeding were done manually for experimental crops at each elevation (Table 2).

2.5 Plant Sampling and Measurements

Samples of experimental maize and mungbean plants and their parts were taken at maturity. Actual dates of sampling for mungbean were September 4, 10, 16 (2015) and for maize were October 22, 31, 17 (2015) at 1500, 1800 and 2200 m elevations. Five plants of each crop were harvested randomly from each experimental plot at each field site. Plant parts were separated, i.e., pods of mungbean and leaves, stem and ear of maize. Pods of mungbean and ear of maize were threshed and grains were collected. The plant parts and grains were dried in electric oven in the laboratory to a moisture level of 12% for maize and 9% for mungbean. The dried samples were

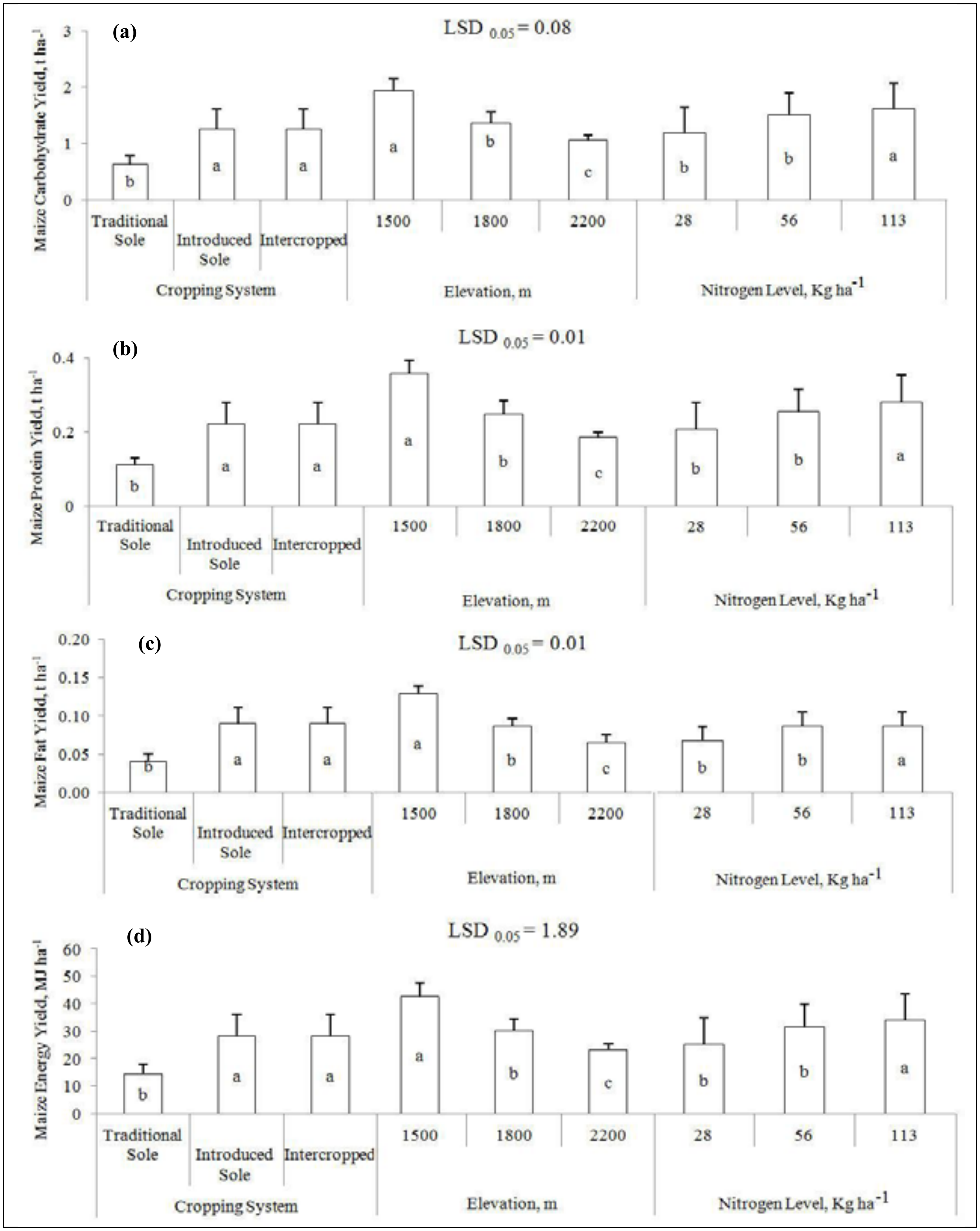

Fig. 3 Effect of cropping system, elevation and nitrogen level on: (a) carbohydrate; (b) protein; (c) fat; and (d) digestible energy yield of maize.

Table 2. Date-wise activities for management of the experiments at three field locations (elevations).

No.	Activity/ Crop Stage		Activity Dates at Various Elevations		
			Danyure, Gilgit (1500 m)	**Gitch, Ghizer (1800 m)**	**Thole, Hunza (2200 m)**
1	Land preparation, field layout, N fertilizer application and seeding of Maize and Mungbean		27-Jun-15	29-Jun-15	05-Jul-15
2	Germination of Mungbean		01-Jul-15	04-Jul-15	10-Jul-15
3	Germination of Maize		04-Jul-15	07-Jul-15	15-Jul-15
4	Thinning, replanting and weeding		20-Jul-15	25-Jul-15	29-Jul-15
5	Application of remaining dose of N fertilizer		21-Aug-15	27-Aug-15	01-Sep-15
6	Harvesting & sampling of Mungbean		04-Sep-15	10-Sep-15	16-Sep-15
7	Harvesting and sampling of Maize		22-Oct-15	31-Oct-15	17-Oct-15
	Total cropping days	Mungbean	56	62	68
		Maize	118	127	113

weighed on a digital balance and their weights were recorded for analysis. Thereafter, average yield per plant calculated while grain production per hectare was computed by multiplying yield per plant with plant population of a hectare.

2.6 Nutritional Composition

The contents of total carbohydrates, protein, fat, and digestible energy in grains of maize and mungbean were computed for both sole and intercropping systems considering the published information [25]. Carbohydrate content in maize and mungbean at 12.0 and 9.0 % moisture of grains was 18.7 and 62.6 g, respectively; protein was 3.27 and 23.9 g, respectively; and fat was 1.35 and 1.2 g, respectively, per 100 g grain. The digestible energy yield in carbohydrates, protein and fats were reported as 17, 16 and 37 kJ g^{-1} of dry weight, respectively. Total energy yield of sole crop of maize and mungbean were estimated taking into consideration the total production of carbohydrates, protein and fat for comparison of cropping systems.

2.7 Land Equivalent Ratio

Land equivalent ratio (LER) was calculated using yield information from sole and intercropped maize and mungbean (Eq.1).

$$LER = \left(\frac{X_i}{Y_i}\right) + \left(\frac{X_j}{Y_j}\right) \qquad \textit{Eq. 1}$$

Where

X_i – grain yield of maize (t ha^{-1}) grown in intercropping; Y_i – grain yield of maize (t ha^{-1}) grown in sole cropping; X_j – grain yield of mungbean (t ha^{-1}) grown in intercropping; Y_j – grain yield of mungbean (t ha^{-1}) grown in sole cropping

2.8 Statistical Analysis

Orthogonal Contrast (OC) method was followed for comparing the performance of sole and intercropping systems as whole and of intercropped crops. Analysis of variance (ANOVA) and Fisher's Protected least significant difference (LSD) techniques were used to find the levels of significance for effect of factors (elevation, cropping system, N level) and comparison of means for recorded parameters i.e., plant height of maize, grain yield and nutritional properties of both maize and mungbean and of cropping system [26].

3. RESULTS

3.1 Maize Performance

Maize plant height was influenced only by the effect of elevation and was greater (P = 0.001) at

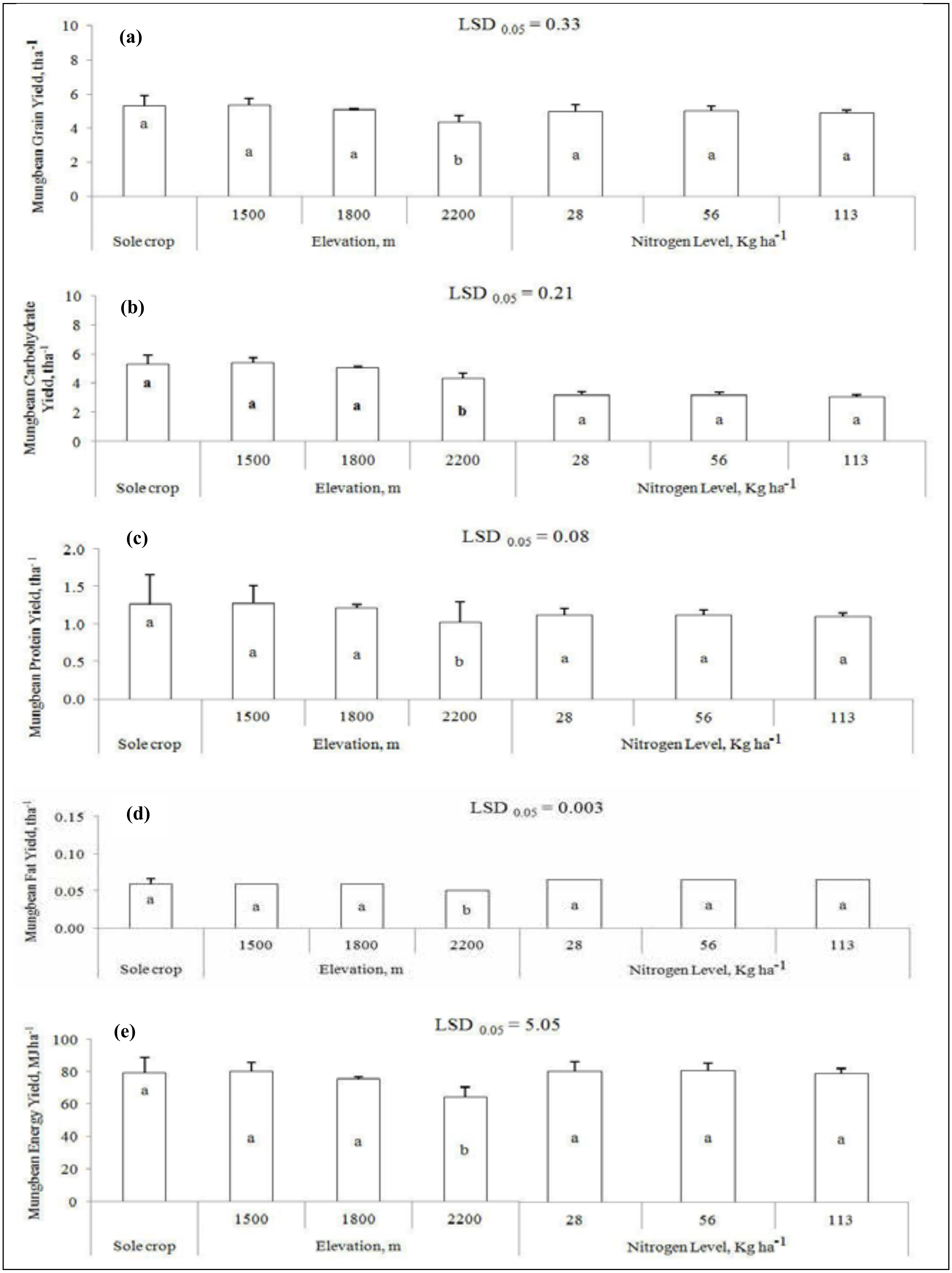

Fig. 4 Effect of cropping system, elevation and nitrogen level on: (a) grain; (b) carbohydrate; (c) protein; (d) fat; and (e) digestible energy yield of mungbean.

both 1800 m (250.8 cm) and 1500 m elevations (242.2 cm) compared to that at 2200 m elevation (163.8 cm) (Fig. 2a). Plant height of maize did not vary due to the influence of other factors, like cropping system and dose of N fertilizer. However, compared to traditionally grown maize (170.7 cm), plant height of the introduced maize cultivar (219.0 cm) was greater ($P = 0.001$).

Average grain yield of maize was 6.7 t ha^{-1}. Among experimental factors (i.e., elevation, cropping system, N level), grain yield of maize was ($P = 0.001$) influenced by elevation and N fertilizer level. It was greater at 1500 m elevation (8.98 t ha^{-1}) compared to that at 1800 m (6.3 t ha^{-1}) and 2200 m (4.9 t ha^{-1}) elevation (Fig. 2b). Grain yield of maize (7.2 t ha^{-1}) was increased successively with increasing N levels; however, effect was noticeable only when N dose was increased from 56 to 113 kg ha^{-1}. Grain yield of introduced maize (6.7 t ha^{-1}) was found to be greater ($P = 0.001$) compared to yield of traditional maize (3.4 t ha^{-1}).

Average estimated contents of carbohydrates, protein, fat, and digestible energy in maize grains were 1.05 t ha^{-1}, 0.81 t ha^{-1}, 0.10 t ha^{-1}, 23.56 MJ ha^{-1}, respectively. Yields of nutritional parameters of maize were varied ($P = 0.001$) due to the site and remained unaffected by cropping system and N dose. Yield of carbohydrates, protein, fat, and digestible energy were higher for 1500 m and 1800 m elevations compared to that at 2200 m elevation (Fig. 3a, b, c). Average values of these parameters of introduced maize were higher ($P = 0.001$) compared to traditional maize.

3.2 Mungbean Performance

Average grain yield of mungbean (*Vigna radiate* L.) was estimated as 4.9 t ha^{-1} for intercropping with maize. Within intercropping the grain yield varied due to elevation ($P = 0.001$) and was higher at 1500 m (5.4 t ha^{-1}) and 1800 m (5.1 t ha^{-1}) compared to 2200 m (4.3 t ha^{-1}) elevations (Fig. 4a, b). Moreover, the grain yield of mungbean decreased ($P = 0.05$) in intercropping compared to its sole cropping (5.3 t ha^{-1}).

Average estimated contents of carbohydrates, protein, fat, and digestible energy in mungbean grains were 3.2 t ha^{-1}, 1.2 t ha^{-1}, 0.06 t ha^{-1}, 76.2 MJ ha^{-1}, respectively. Within intercropping, the contents of these parameters were varied by elevation ($P = 0.001$) and were higher at 1500 m and 1800 m compared to 2200 m (Fig. 4a, b, c, d). Estimates of these parameters were lower ($P = 0.05$) in intercropping with maize compared to sole cropping.

3.3 Total Nutritional and Energy Yield

Sole cropping system of maize and intercropping system comprising maize and mungbean were compared for estimated values of nutritional parameters as influenced by elevation, cropping system and N dose. Estimated productions of carbohydrates, protein, fats and digestible energy varied due to elevation ($P = 0.001$), cropping system but not by the N level. The production of these parameters was higher at 1500 m and 1800 m compared to 2200 m elevation. Intercropping system produced greater contents of the nutritional parameters compared to both introduced and traditional sole cropping of maize (Fig. 5a, 5b, 5c, 5d).

3.4 Land Equivalent Ratio

The LER described land area required for a sole crop to get the same produce from an intercropping managed under same conditions. The LER of 1.0 indicates intercropping produces same yields as of sole cropping, and above 1.0 show greater yields of intercropping than sole crop. The highest LER was recorded at 1500 and 1800 m elevations (2.0) followed by 2200 m elevation (1.9). However, there is no difference in LER (1.9) for different levels of N applied (Table 3).

4. DISCUSSION

Maize, cv. Pahari, is grown on most of agricultural land in the study area because of its early maturity. But it is characterized with short stature, lower biomass and lesser grain yield compared to another recommended and high yielding variety of maize, i.e., cv. Azam. The new maize variety was tested through research experiments conducted at different elevations for its sole cropping and also

Table 3. Effect of elevation and N dose on land equivalent ratio (LER) estimated from grain yields of maize and mungbean grown in sole and intercropping.

Treatment	Maize Yield (t ha^{-1})		Mungbean Yield (t ha^{-1})		LER
	Sole	Intercropped	Sole	Intercropped	
Elevation (m above MSL)					
1500	8.9±1.1	9.1±0.7	5.8±0.3	5.4±0.4	2.0
1800	6.3±0.9	6.4±0.5	5.4±0.6	5.1±0.1	2.0
2200	5.1±0.4	4.7±0.3	4.8±0.5	4.3±0.4	1.9
N dose (kg ha^{-1})					
28	6.3±0.8	6.3±0.6	5.3±0.5	4.9±0.4	1.9
56	6.7±0.5	6.7±0.5	5.3±0.5	5.0±0.3	1.9
113	7.3±1.2	7.1±0.4	5.3±0.5	4.8±0.2	1.9

intercropping with mungbean. Experimental sites have different climatic conditions due to variation of elevation [15]. Plant height, grain yield and associated nutritional parameters were greater in case of Azam variety compared to Pahari variety. This could be due to different genetic potential of varieties as also observed by Olakojo and Iken [27], Tahir et al. [28], Akbar et al. [29] and Hussain et al. [30].

Maize and mungbean responded differently to different elevation conditions as indicated for growth and yield parameters. Selected elevations have different length of suitable weather conditions for the experimental crops which influenced their growth and yield and thereby affected land equivalent ratio and associated production levels of carbohydrates, protein, fat, and digestible energy contents. To some extent environmental conditions of 1500 and 1800 m elevations are close proximity though not reflected significant variation in growth and yield components the crops. Varied response of maize to different elevations was also noted by Wilson et al. [31], Ekasingh [32] and Xue-jun et al. [33].

Growth and yield of intercropped maize and mungbean were lower compared to their sole stands owing to competition in intercropping of above and below ground resources i.e., light, nutrients, water etc. Decrease in growth and yield of crops in intercropping systems has been reported by several scientists [34, 35, 7].

Nitrogen is the most important major nutrient for plant growth and grain production. Increasing quantity of N application increases production to a certain level thereafter increase is not noticeable. Sometimes excessive application of N leads to lodging and disease attack for crop. Maize with respect to its grain yield responded positively to increasing application of N, however, other parameters remained unaffected. The increase of maize growth and yield due to N is in agreement with studies of Arif et al [36], Saleem et al. [37] and Khogali et al. [38].

5. CONCLUSIONS

This study explored the merits of growing improved maize cv. Azam over the traditionally grown cv. *Pahari*, and investigated advantages of intercropping maize with mungbean over its sole cropping and the appropriate dose of N fertilizer to be adopted. Maize cv. Azam exhibited superior genetic potential by virtue of its better growth, yield and nutritional parameters compared to the traditionally grown *Pahari* variety. In mountainous areas, lower elevations provide more conducive conditions for greater grain production of both maize and mungbean. This study also revealed that in between the rows of maize, rows of mungbean can be grown as intercrop to increase diversity, cropping intensity and land productivity. Moreover, application of N fertilizer to maize in split doses enhances its grain yield and associated nutritional and economical benefits.

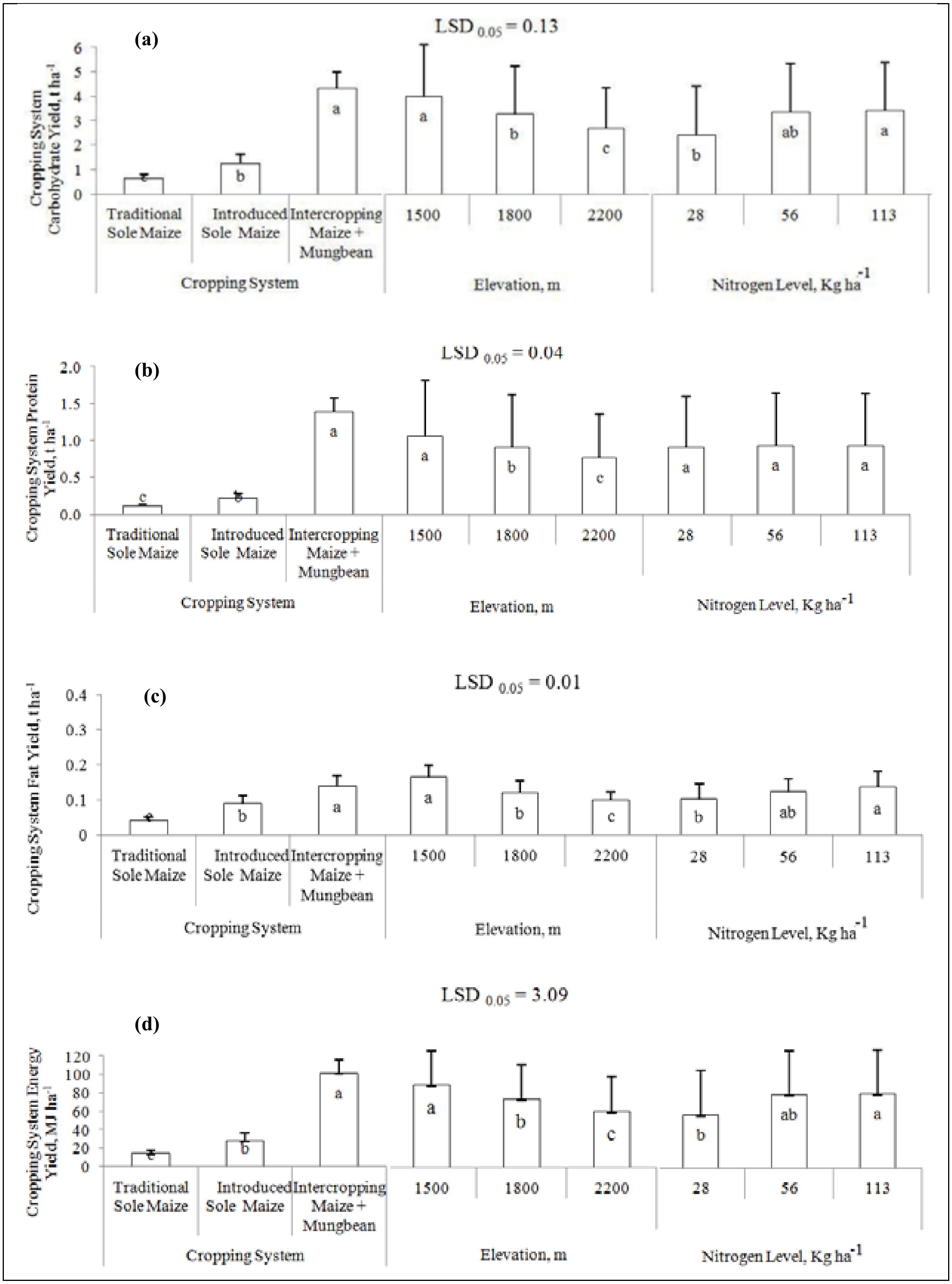

Fig. 5 Effect of cropping system, elevation and nitrogen level on: (a) carbohydrate; (b) protein; (c) fat; and (d) digestible energy yield of the cropping system.

6. ACKNOWLEDGEMENTS

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