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SUITABILITY OF MAIZE-LEGUME INTERCROPS WITH OPTIMUM ROW RATIO IN MID HILLS OF EASTERN HIMALAYA, INDIA

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ABSTRACT

Maize (*Zea mays* L.) being a widely space crop were tried with different combinations of legumes cowpea (*Vigna unguiculata* L. Walp), frenchbean (*Phaseolus vulgaris* L.) and blackgram (*Vigna mungo* L.) as intercrops at different planting geometry to find out their suitability during 2009, 2010 and 2011 at eastern Himalayan, Arunachal Pradesh, India. Three experiments were carried out in sequence to identify suitable planting geometry to accommodate intercrops, screening best legume crops and subsequently best performed row ratio of maize and legume crops were intercropped in third experiment with 1:1, 1:2 and 1:5 row proportions. Sole maize gave the maximum grain yield with 4571.1 kg ha^{-1}, whereas, stover yield was highest with maize-cowpea intercrop at 1:2 row ratios (8013.4 kg ha^{-1}) and 57.1 kg ha^{-1} day^{-1} production efficiency followed by frenchbean and least with blackgram. Competition indices like land equivalent ratio (LER) was highest with 1:2 row ratio of maize-frenchbean (1.66), land equivalent coefficient (0.67). But, highest area time equivalent ratio (ATER) noticed with 1:2 row ratio of maize-blackgram (1.47). Relative crowding coefficient (K) and competition ratio were noticed higher with 1:2 row ratio of maize-cowpea, whereas, cowpea combinations has better crowding coefficient and blackgram combinations registered better competitiveness. Monetary advantage index (MAI) was 6433.2 with 1:2 row ratio of maize-blackgram followed by maize-cowpea and lowest with maize-frenchbean with the trend of 1:2>1:5>1:1 row ratios.

Key words: Competition indices, Intercropping, Maize, Monetary advantage index, Planting geometry

INTRODUCTION

Eastern Himalaya of India is a rocky terrain with hills and sloppy land, where slash and burn cultivation, locally known as "*jhum kheti*" is commonly practiced.

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Farmers put as many as 35 crops without following any row arrangement and seeding ratio resulted competition and yield reduction (Choudhary et al., 2012). But in recent years, trend of agricultural production system have changed drastically to achieve the high productivity and promote sustainability over time (Dhima et al., 2007). Intercropping is promising production technology which not only ensure efficient utilization of natural resources like light, nutrient, water and space (Ghosh, 2004; Dhima et al., 2007), but also conserve it by reducing soil erosion and lodging, suppress weed growth thereby helps in yield increment and maintain greater stability in crop yields (Banik et al., 2006). Intercropping is a viable agronomic means of risk minimizing farmers' profit and subsistence- oriented, energy efficient and sustainable venture (Sheoran et al., 2010). Since maize (*Zea mays* L.) is a widely spaced crop, inter row space could be profitably utilized for legumes. Maize- legumes intercropping system, besides increasing productivity and profitability also improves soil health, conserves soil moisture and increases total out turn. Inclusion of legumes as intercrop with cereals not only supply the additional nutrients to crop plant by converting and fixing atmospheric nitrogen in available form through symbiosis with *rhizobial* strains also conserve the soil. However, several factors like cultivar selection, seeding ratio, planting pattern and competition between mixture components affect the growth of species in intercropping (Singh et al., 2008).

A number of indices such as land equivalent ratio (LER), relative crowding coefficient (RCC), competitive ratio (CR), actual yield loss (AYL), monetary advantage index (MAI), and intercropping advantage (IA) have been proposed to evaluate the efficient intercropping system (Dhima et al., 2007). Indices describe competition with row ratios of system for economic advantages and land utilization efficiency. Competition among component crops is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Spatial arrangement and plant population in an intercropping system have important effects on the balance of competition between component crops and their overall productivity (Ghosh, 2004; Dhima et al., 2007). However, such indices have not been used for maize with different legumes as intercrops to evaluate the competition among species and also economic advantages of each intercropping system in the eastern Himalaya. Therefore, the present study was conceived to find out the suitable planting geometry of maize to accommodate intercrops and screen best legume crops under mid hill condition of eastern Himalaya for higher productivity.

MATERIALS AND METHODS

Climatic and soil characteristics of experimental site

The field experiments were conducted at the experimental farm of ICAR research complex for NEH Region, Basar, Arunachal Pradesh, India (27°95'N latitude and 94°76'E longitude, 631 m above MSL, under humid sub tropical climate) during 2009 to 2011. The daily temperature during a year varies widely between minimum 4°C and maximum 35°C. The experimental site received average annual rainfall of 2400 mm with high degree of monthly variations. The soil of experimental site is silty loam in texture, acidic in reaction (pH 5.3), high in organic carbon (Walkaley and Black, 1.32 g kg^{-1}), low in available nitrogen (alkaline permanganate N, 193.8 kg ha^{-1}), low in available phosphorus (Bray P, 10.4 kg ha^{-1}) and medium in available potassium (ammonium acetate K, 210.5 kg ha^{-1}).

Imposition of experiments

Experiment-1: Identifying suitable planting geometry for maize

The first field experiment was conducted during rainy season (2009 and 2010) with four planting geometry of maize *viz.*, 60 x 20, 60 x 30, 90 x 20 and 90 x 30 cm in a randomized complete block design (RCBD) with five replications. The plot size was 4.8 m x 4.0 m. Maize cv. *All rounder* was sown in the first fortnight of April as per treatment. Two seeds were placed in individual site and thinned after eight days to maintain one plant at each site and harvested 125 days after sowing (DAS). Maize crop was fertilized with 40 kg N, 60 kg P and 40 kg K ha^{-1} in the form of urea (46% N), single super phosphate (16% P) and muriate of potash (60% K), at the time of sowing. The remaining 40 kg of N was top dressed at 40 DAS. Standard scientific cultivation practices are followed to obtain good crop yield.

Experiment-2: Evaluation of different legume crops

The second field experiment was conducted during rainy season of 2009 and 2010 with five legume crops *viz.*, cowpea (var. CP-04), frenchbean (var. Anupama), blackgram (var. PU-31), groundnut (var. ICGS-76) and soybean (var. JS-335) in a randomized complete block design (RCBD) with four replications. The plot size was 3.6 x 2.0 m with spacing of 30 x 10 cm for all the crops. Crops were sown at first fortnight of April and fertilized as per recommended dose, cowpea (25 kg N, 75 kg P and 60 kg K ha^{-1}), frenchbean (62.5 kg N, 100 kg P and 75 kg K ha^{-1}), blackgram, groundnut and soybean (25 kg N, 60 kg P and 50 kg K ha^{-1}). Standard scientific cultivation practices recommended for each crop was followed to obtain good yield.

Experiment-3: Studying the influence of intercrop on the main and supplementary crops

Best suitable options are selected from the experiment 1 and 2 and third experiment was conducted using those combinations along with sole maize (90 x 20 cm). Cowpea, frenchbean and blackgram were selected as intercrops. The field experiment was conducted during the rainy season of 2010 and 2011 on maize with three selected legumes with 1:1, 1:2 and 1:5 row ratios with sole maize and three legumes (data no presented). The recommended basal dose of fertilizer for maize (40 kg N, 60 kg P and 40 kg K ha^{-1}), cowpea (25 kg N, 75 kg P and 60 kg K ha^{-1}), french bean (62.5 kg N, 100 kg P and 75 kg K ha^{-1}) and blackgram (25 kg N, 60 kg P and 50 kg K ha^{-1}) were applied at sowing and incase of maize, remaining nitrogen (40 kg N ha^{-1}) was top dressed at 40 DAS. For the intercropping treatments, fertilizers were applied proportionate to the sole optimum population for main and intercrop separately.

Observations

Yield of maize was recorded from the net plot area (2.4 x 3.0 m) for experiment 1 and 3. Cobs were harvested manually at physiological maturity period and the yield was recorded at 15% moisture content. Yield of legumes crops were recorded from net plot (2.4 x 1.6 m) for experiment 2 and 3. Cowpea and blackgram was plucked four times and frenchbean was plucked twice, whereas, soybean and groundnut were harvested once at the end of physiological maturity.

In intercropping, yield was recorded for individual companion crop along with maize and subjected to various intercropping indices. The yield advantage of intercropping was determined by calculating land equivalent ratio (LER), competition ratio (CR) and monetary advantage index (MAI) according to the methods described by Willey and Rao (1980). Land equivalent coefficient (LEC) as suggested by Adetiloye et al. (1983), area time equivalent ratio (ATER) as proposed by Hiebsch and McCollum (1987), relative crowding coefficient (K), aggressivity (A) was measured as suggested by Mc Gilchrist (1965), whereas, actual yield loss (AYL) and intercropping advantage (IA) was calculated as recommended by Banik et al. (2000).

The different parameters were statistically analyzed using SAS 9.2 programme. The significance of treatment effects was determined using the F-test. The significance of the difference between means of two treatments was tested using least significant difference (LSD) at 5% probability level. In most of the cases, there was no significant effect of year and/or year x intercropping; therefore, pooled results were presented.

RESULTS AND DISCUSSION

Rainfall distribution

During the experimentation it was noticed that the overall rainfall was comparatively lower during 2009 followed by 2011 and highest during 2010. July of 2010 and 2011 was the rainy month, whereas, August was the rainy month during 2009. But overall, the rainfall during the season was nearer to normal rainfall of the area, except 2009 (Figure 1).

Maize yield influenced by planting geometry

Planting geometry of maize with 60 x 30 and 90 x 20 cm has 55,500 plants ha^{-1} whereas; 60 x 20 cm and 90 x 30 cm registered 83,300 and 37,000 plants ha^{-1} respectively (Table 1). Maximum grain yield of maize was recorded with 60 x 30 cm spacing (4434 kg ha^{-1}) but was statistically comparable with 90 x 20 cm and significantly (p<0.05) superior over maize yield obtained with 90 x 30 cm. Planting geometry of maize at 90 x 30 cm and 60 x 20 obtained yield reduction of 22.15 and

7.72%, respectively than the 60 x 30 cm. This might be due to better utilization of solar radiation, space, nutrients etc. which, induce the plant to produce more yield attributes and finally contributed to higher grain yield. Stover yield was maximum with 60 x 20 cm (6508 kg ha^{-1}) followed by 60 x 30 and 90 x 20 cm and lowest with 90 x 30 cm. This was mainly due to more plants per unit area, resulted in more vegetative growth but these could not convert to yield attributes. Consequently, harvest index was higher in 90 x 20 cm (0.42) followed by 60 x 30 cm but was statistically comparable and least with 90 x 30 cm.

Legume crop yield

Individually legume yield was recorded and highest economic yield was obtained in cowpea (5267.5 kg ha^{-1}) followed by frenchbean and blackgram (Table 2). Similarly, stover yield and harvest index followed the trend of economic yield and the highest for cowpea (8057.5 kg ha^{-1} and 0.40, respectively). The performance of various legumes was evaluated with the cowpea equivalent yield and the highest was obtained with cowpea which was 92.8% higher than frenchbean followed by groundnut and blackgram (27.2 and 17.3% respectively). As per the cowpea equivalent yield and need of the farmers' three legume viz., cowpea, frenchbean and blackgram were selected as intercrops with maize.

Grain and stover yield, maize equivalent yield, production efficiency and land equivalent ratio

Maximum grain yield was recorded with sole maize (4571.7 kg ha^{-1}) followed by 1:1 row ratio of maize-cowpea (4413.3 kg ha^{-1}) and lowest yield under 1:5 of maize-frenchbean (2606.7 kg ha^{-1}). However, it was noticed that, maize in association with maize-blackgram (4411.7 and 4327.7 kg ha^{-1} under 1:2 and 1:1 row ratio, respectively) and frenchbean (4346.7 and 4146.7 kg ha^{-1} under 1:2 and 1:1 row ratio, respectively) produced similar trend of maize yield as per the above row ratio (Table 3). This was mainly due to better utilization of resources available at site and least competition offered. Similar finding was also reported by Ghosh (2004) and Dhima et al. (2007). Stover yield was recorded highest with 1:2 of maize-cowpea (8013.4 kg ha^{-1}) followed by 1:2 of maize-frenchbean (7922.5 kg ha^{-1}). However, it was noticed that the trend of stover yield was highest for 1:2 row ratios followed by 1:1 and lowest with 1:5 row ratios. Intercrop yield was mainly dependent on row ratios, it was noticed that as row ratio increased, plant population of intercrop gradually increased and registered higher intercrop yield. Therefore, 1:5 row ratios has higher yield followed by 1:2 and 1:1 row ratio.

The maize equivalent yield (MEY) was higher with 1:2 row ratios followed by 1:5 row ratios of maize-cowpea, which were 84.8 and 64.4%, respectively higher over sole maize. Different row ratio of frenchbean and blackgram registered considerably lower MEY than maize-cowpea system but was better than sole maize. The productivity followed the trend of MEY and was higher with 1:2 of maize-cowpea followed by 1:5 of maize-cowpea. It was also noticed that productivity was followed the trend of 1:2>1:1>1:5 row ratios, which was registered the increment of 55.3%>32%>27.8%, respectively whereas, among crops trend with cowpea>frenchbean>blackgram (Table 3).

Land equivalent ratio (LER) reflected the extra advantages of intercropping system; the partial LER of maize was lowered only by 3% with 1:2 row ratio of maize-cowpea/blackgram and 1:1 row ratio of maize-cowpea over sole maize followed by 1:2 of maize-frenchbean and 1:1 of maize-blackgram with 5% reduction (Table 3). In contrary, partial LER of intercrop was lowered by 15% with 1:5 row ratio of maize-frenchbean/blackgram over sole intercrops. The cumulative LER was noticed 31-66% higher than sole maize. This was due to considerably higher yield harvested. However, 1:2 row ratios have higher LER followed by 1:5 and 1:1, and among crop frenchbean was higher followed by cowpea and then blackgram.

Land equivalent coefficient, area time equivalent ratio, aggressivity and relative crowding coefficient

Land equivalent coefficient followed the trend of LER and measured highest LEC with 1:2 of maize-frenchbean (Table 4). Realistic comparison of the yield advantage and resource utilization of intercropping system was assessed by ATER. It was noticed that 1:2 row ratio of maize-blackgram has 47% higher ATER followed by 1:2 of maize-cowpea. Among the row ratio, 1:2 had 32-47% higher ATER followed by 1:1 and lowest with 1:5 row ratios, whereas, among the intercrops, the trend with blackgram>cowpea>frenchbean was recorded (Table 4). Similar findings were reported by Muhammad et al. (2008) in cotton+ cowpea intercropping and Singh et al. (2008) in maize based intercropping.

Aggressivity (A) assess the dominance of the crop species in intercropping, A of maize was measured more negative value at 1:1 row ratio of maize-frenchbean followed by 1:2 row ratio of maize-cowpea. However, lowest negative value for A of maize was noticed under 1:5 row ratio (Table 4). A of intercrops were noticed inverse trend over A of maize. Similar findings were also reported by Khan and Khaliq (2004).

Relative crowding coefficient (K) of maize was higher under 1:2 row ratio of maize-cowpea followed by 1:2 row ratio of maize-blackgram. The K of maize was recorded more than 1 for all the row ratios, which showed that the cereals were dominated over the legumes (Table 4). Such result was expected since cereals are more competitive than legumes (Ghosh, 2004; Dhima et al., 2007; Wahla et al., 2009). In contrary to this, K of intercrop was higher on 1:5 row ratios. This was due to lowered maize density and higher density of intercrops. The total K was followed the trend of 1:2>1:1>1:5 row ratio with cowpea>blackgram>frenchbean.

Competition ratio, actual yield loss and monetary advantage index

The competition ratio (CR) for maize was higher on 1:5 row ratios of maize-cowpea followed by blackgram and frenchbean with similar row ratio (Table 5). It was observed that row ratio has followed the trend of 1:5>1:2>1:1, whereas, among the crops blackgram>cowpea>frenchbean. Similarly, CR for intercrop was higher under 1:1 row ratio followed by 1:2 and lowest with 1:5 row ratio. The trend of CR in intercrop was highest with frenchbean followed by cowpea lowest with blackgram. Similar finding was also corroborated by Banik et al. (2000).

Actual yield loss (AYL) offered more accurate information than the other indices on inter- and intra-specific competitions in intercropping systems. AYL of maize was lower under 1:1 row ratio with maize-frenchbean. Frenchbean has recorded more yield loss followed by blackgram and lowest with cowpea (Table 5). It is also evident that intercropping of frenchbean has more yield loss followed by cowpea and lowest with blackgram.

Monetary advantage index (MAI) was higher with 1:2 of with maize-blackgram followed by 1:5 of maize-blackgram and lower with 1:1 row ratio of maize-frenchbean. Table 5 clearly depicted that among the maize-legume intercropping, blackgram has given highest monetary advantage followed by cowpea and lowest with frenchbean. Among the different row ratio, 1:2 gave the highest monetary advantages followed by 1:5 and the lowest with 1:1. MAI was mainly influenced by market price of produce and economic yield harvested, resulted in higher MAI. Ghosh (2004) and Dhima et al. (2007) also reported that if LER and K were higher then MAI also get improved. Higher seed yield and net income under planting pattern with differed row ratios may be explained in higher total productivity under intercropping with relatively less input investment (Banik et al., 2006).

CONCLUSION

The results of our study suggest that planting geometry of maize with 60 x 30 cm and 90 x 20 cm gave the similar yield. Growers of the region have more apathy towards cowpea, frenchbean and blackgram than others. The different row ratio of legumes on maize showed significant impact on productivity and various competition indices. Most of the intercropping indices were better with 1:2 of maize-cowpea with yield advantages of intercropping and optimum utilization of the environmental resources over sole maize. Among the legumes, blackgram had highest monetary benefit followed by cowpea. Therefore, in sole maize area, maize with 1:2 and 1:5 row ratios of cowpea and blackgram may be included to obtain higher system productivity. Apart from these, further studies are needed to determine how intercropping can be helpful to curtail inorganic nutrient use and weed suppression.

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Table 1: Yield and harvest index of maize with different planting geometry (mean value of 2009 and 2010)

Planting geometry	Plant population	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
60 x 20 cm	83,300	4092	6508	0.38
60 x 30 cm	55,500	4434	6258	0.41
90 x 20 cm	55,500	4424	6196	0.42
90 x 30 cm	37,000	3452	5424	0.39
LSD at 0.05		287.6	202.7	0.01

Note: LSD: least significant difference; different letters in the same column are statistically significant at P=0.05% and same letters are statistically similar

Table 2: Yield and harvest index of different legumes crop (mean value of 2009 and 2010)

Crops	Days to mature	Economic yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)	Cowpea equivalent yield (kg ha^{-1})
Cowpea	83	5267.5±132.0	8057.5±328.5	0.40±0.010	5267.5
French bean	75	3415.0±115.0	5440.0±82.9	0.39±0.006	2732.0
Black gram	107	1335.0±44.4	3062.5±137.7	0.31±0.006	3204.0
Groundnut	110	1287.5±29.9	3212.5±85.4	0.29±0.005	3476.3
Soybean	112	1842.5±123.4	2337.5±188.7	0.37±0.013	3040.1
LSD at 0.05					292.47

Note: price of the produce (Rs ton^{-1}): maize: 9000; cowpea: 10000; frenchbean: 8000; blackgram: 24000; soybean: 16500; groundnut: 27000; [1$ equivalent to 58 Rs]

LSD: least significant difference; ± standard deviation from mean; different letters in the same column are statistically significant at P=0.05% and same letters are statistically similar

Table 3: Grain and stover yield, maize equivalent yield, production efficiency and land equivalent ratio as influenced by maize-legumes intercropping (mean value of 2010 and 2011)

Crops	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})*	Intercrop yield (kg ha^{-1})	Maize equivalent grain yield (kg ha^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Land equivalent ratio of maize	Land equivalent ratio of intercrop	Total land equivalent ratio
Sole maize	4571.7a	7860.0	-	4571.7	32.0	-	-	-
1:1 of maize-cowpea	4413.3b	7740.0	2280.0	6938.4	47.9	0.97	0.43	1.39
1:2 of maize-cowpea	4428.3b	8013.4	3620.0	8450.5	57.1	0.97	0.68	1.65
1:5 of maize-cowpea	2736.7d	4270.0	4300.0	7514.5	49.8	0.60	0.81	1.41
1:1 of maize-frenchbean	4161.7c	7515.0	1953.3	5898.0	40.7	0.91	0.48	1.40
1:2 of maize- frenchbean	4346.7b	7922.5	2841.7	6872.6	46.8	0.95	0.71	1.66
1:5 of maize- frenchbean	2606.7d	4255.0	3322.5	5560.0	36.8	0.57	0.83	1.40
1:1 of maize-blackgram	4327.7b	7776.7	465.0	5566.7	38.1	0.95	0.36	1.31
1:2 of maize- blackgram	4411.7b	7755.0	868.3	6727.2	45.2	0.97	0.68	1.64
1:5 of maize- blackgram	2661.7d	4789.2	1071.7	5519.5	36.1	0.58	0.83	1.41
LSD at 0.05	132.53	401.85		228.65	1.86	0.03	0.04	0.05

LSD: least significant difference, *stover yield of maize and intercrop is jointly presented as there was no price difference for stover yield

Table 4: Land equivalent coefficient, area time equivalent ratio, aggressivity and relative crowding coefficient as influenced by maize-legumes intercropping (mean value of 2010 and 2011)

Crops	Land equivalent coefficient	Area time equivalent ratio	Aggressivity of maize	Aggressivity of intercrop	Relative crowding coefficient of maize	Relative crowding coefficient of intercrop	Total relative crowding coefficient
1:1 of maize-cowpea	0.41	1.22	-0.43	0.42	28.88	0.76	21.72
1:2 of maize-cowpea	0.66	1.36	-0.13	0.13	41.69	2.15	90.46
1:5 of maize-cowpea	0.49	1.06	-0.06	0.06	1.50	4.36	6.58
1:1 of maize-frenchbean	0.44	1.17	-0.66	0.66	11.31	1.01	10.24
1:2 of maize- frenchbean	0.67	1.32	-0.19	0.19	19.89	2.86	56.86
1:5 of maize- frenchbean	0.47	1.00	-0.12	0.12	1.34	5.30	6.95
1:1 of maize-blackgram	0.34	1.04	-0.22	0.22	19.74	0.57	11.11
1:2 of maize- blackgram	0.65	1.47	-0.12	0.12	30.40	2.11	61.63
1:5 of maize- blackgram	0.48	1.18	-0.11	0.11	1.41	5.13	7.08
LSD at 0.05	0.03	0.09	0.08	0.07	5.34	1.21	15.87

LSD: least significant difference

Table 5: Competition ratio, actual yield loss and monetary advantage index as influenced by maize-legumes intercropping (mean value of 2010 and 2011)

Crops	Competition ratio of maize	Competition ratio of intercrop	Actual yield loss of maize	Actual yield loss of intercrop	Monetary advantage index
1:1 of maize-cowpea	0.69	1.44	-0.03	0.39	2690.8
1:2 of maize-cowpea	0.88	1.13	-0.03	0.10	3746.3
1:5 of maize-cowpea	0.95	1.06	0.00	0.05	2759.5
1:1 of maize-frenchbean	0.60	1.73	-0.09	0.57	2404.6
1:2 of maize- frenchbean	0.85	1.20	-0.05	0.14	3356.3
1:5 of maize- frenchbean	0.89	1.13	-0.05	0.07	2414.4
1:1 of maize-blackgram	0.81	1.23	-0.05	0.17	3887.7
1:2 of maize- blackgram	0.89	1.13	-0.03	0.09	6433.2
1:5 of maize- blackgram	0.90	1.11	-0.03	0.08	4835.8
LSD at 0.05	0.06	0.08	0.03	0.05	255.32

LSD: least significant difference

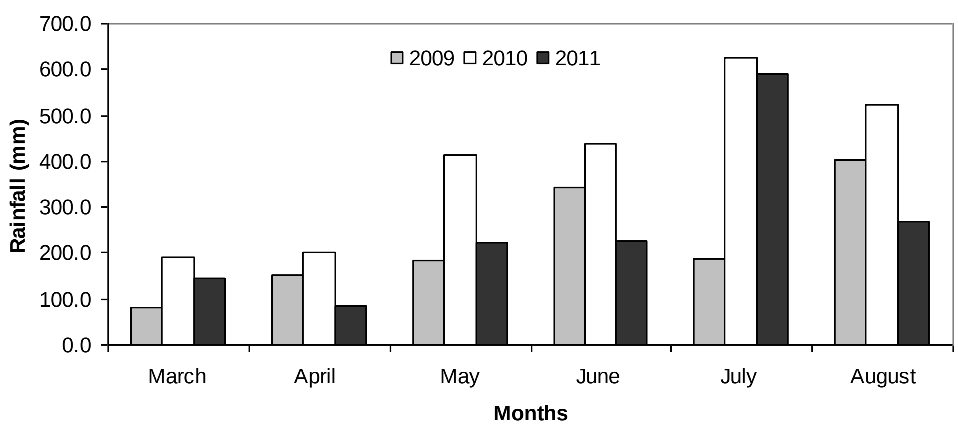

Figure 1: Rainfall distribution during the experimental period (2009, 2010 and 2011)