Journal of Agrometeorology 12 (1): 27-32 (June 2010)

Modeling effects of rainfall and soil moisture on productivity of maize and black gram in semi-arid vertisols

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ABSTRACT

Based on field experiments conducted during 1998 to 2006 in a semi-arid vertisol at Arjia on maize and blackgram crop an attempt was made to assess the effect of rainfall received during June to September and the soil moisture at the times of sowing and harvest on the biological yield. The study was conducted in 3 blocks of maize, blackgram and maize + blackgram by superimposing 9 fertilizer treatments. The soil moisture at sowing and harvest and biological yield attained by treatments differed significantly based on ANOVA in different years. The treatment–wise regression models of yield through rainfall of June to September and soil moisture at sowing and harvest had a predictability of 0.62 to 0.98 in maize block, 0.73 to 0.98 in blackgram block and 0.54 to 0.98 in maize + blackgram block.

Key words : Rainfall, soil moisture, regression models

Maize (*Zea mays*) is an important cereal grown under rainfed conditions in different states of India. It is grown in monsoon season (June to September) in Rajasthan, Punjab, Jammu and Kashmir, Andhra Pradesh, Karnataka, Maharashtra and other states as a rainfed crop. Maize is grown both as a sole crop and also in combination with other rained crops as an intercrop. The quantity of rainfall and its distribution would significantly influence the fertilizer effect on crop yield. Apart from rainfall and available soil moisture, the yield of a crop is greatly influenced by fertilizer practice under rained conditions. Maruthi Sankar *et al.,* (2006) assessed the efficiency of tillage and fertilizer practices for different rainfed crops grown under varying soil and agro-climatic situations in India. Prihar and Gajri (1988) examined the usefulness of fertilization of rained crops under dryland conditions. There is a need to identify a superior fertilizer practice for attaining a sustainable productivity of maize under semi-arid vertisols. Although maize has a lower water requirement compared to other rainfed crops, there is need to correctly identify a superior fertilizer practice for attaining a stable and sustainable yield under rainfed conditions. The regression models discussed by Draper and Smith (1998) and Maruthi Sankar (1986) would be useful for describing the effects of rainfall and soil moisture on yield and assessing the superiority of fertilizer treatments for maize under rainfed conditions. Nema *et al.,* (2008) evaluated the effects of crop seasonal rainfall and available soil moisture on the productivity of pearl millet using regression models. The sustainability of treatments could be assessed based on the procedure adopted by Vittal *et al.,* (2002 and 2003) and Maruthi Sankar *et al.,* (2006).

MATERIAL AND METHODS

Nine field experiments were conducted in separate blocks of maize, blackgram and maize + blackgram in *kharif* season (June to September) during 1998 to 2006 in a semi-arid vertisol at Dryland Farming Research Station, Arjia in Bhilwara district of Rajasthan under All India Coordinated Research Project for Dryland Agriculture. The experiments were conducted with 9 fertilizer treatments of organic and inorganic sources viz., control, 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost), 15 kg N (compost) + 10 kg N ha^{-1} (urea), 15 kg N (compost) + 20 kg N ha^{-1} (urea), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea), 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) and 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) in a Randomized block design with 3 replications. A common dose of 30 kg P ha^{-1} was applied in all the plots. Arjia is situated at Latitude of 24.2° North, Longitude of 74.2° East and an Altitude of 242.2 meter above mean sea level. A recommended spacing of 60 cm for maize and 30 cm for blackgram were adopted and the crops were grown in a net plot size of 9.6 x 5 m in each season. A seed rate of 25 kg ha^{-1} for maize and 15 kg ha^{-1} for blackgram and all other agronomic practices the two crops were adopted. A recommended fertilizer dose of 50 kg N (urea) + 30 kg P ha^{-1} is applied for maize at the time of sowing in Rajasthan. The study was conducted with the objectives of (i) assessing effects of monthly rainfall received during June to September and soil moisture at sowing and harvest on crop yield; and (ii) selection of a superior treatment for attaining sustainable yield over years.

Rainfall and its distribution in different years

The details of date of sowing and harvest of maize and

Table 1: Date of sowing and harvest of maize and black gram and rainfall received at Arjia

Year	Maize			Black gram			Rainfall (mm)				
	DOS	DOH	CGP	DOS	DOH	CGP	Jun	Jul	Aug	Sep	CRF
1998	10-Jul	2-Oct	85	10-Jul	2-Oct	85	63	126	66	104	359
1999	28-Jul	3-Oct	68	28-Jul	3-Oct	68	48	317	132	37	534
2000	27-Jul	19-Oct	85	27-Jul	12-Oct	78	11	278	131	3	424
2001	16-Jun	19-Sep	96	16-Jun	15-Sep	92	57	412	249	16	734
2002	8-Aug	19-Oct	73	8-Aug	8-Oct	62	45	6	175	13	239
2003	8-Aug	2-Oct	56	8-Aug	10-Sep	34	129	173	136	30	468
2004	9-Jul	9-Oct	93	9-Jul	22-Sep	76	55	272	599	52	978
2005	4-Jul	27-Sep	86	4-Jul	27-Sep	86	38	126	38	180	381
2006	29-Jun	29-Oct	123	29-Jun	29-Oct	123	168	290	479	96	1033
Mean			*85*			*78*	*49*	*124*	*192*	*57*	*572*
CV			*22*			*31*	*71*	*56*	*86*	*97*	*49*

DOS : Date of sowing DOH : Date of harvest CG : Crop growing period
CRF : Crop seasonal rainfall (mm) CV : Coefficient of variation (%)

blackgram, crop growing period, and rainfall received during June to September in different years along with mean and variation (%) over years are given in Table 1. The rainfall received in June ranged from 11 mm in 2000 to 168 mm in 2006 with a mean of 49 mm and variation of 71%. In July, a minimum rainfall of 6 mm was received in 2002, while a maximum of 412 mm in 2001 with a mean of 124 mm and variation of 56%. The August rainfall ranged from 38 mm in 2005 to 599 mm in 2004, while September rainfall ranged from a minimum of 3 mm in 2000 to 180 mm in 2005. August and September received a mean rainfall of 192 and 57 mm with a variation of 86 and 97% respectively during 9 years.

A minimum crop seasonal rainfall of 239 mm (77.9% of annual rainfall) was received in 2002 compared to a maximum of 1033 mm (98.2% of annual rainfall) in 2006. The total rainfall received during June to September was above a mean rainfall of 572 mm in 2001 (734 mm), 2004 (978 mm) and 2006 (1033 mm), while it was below in the remaining 6 years. June received an above mean rainfall of 49 mm in 7 years (except 2000 and 2005), while July received an above mean rainfall of 124 mm in 8 years (except 2002). August had an above mean rainfall of 192 mm in 2001, 2004 and 2006, while September had an above mean rainfall of 57 mm in 1998, 2005 and 2006. In maize, the earliest date of sowing (DOS) was on 16^{th} June in 2001, while the latest was on 8^{th} August in 2002 and 2003. The earliest date of harvest (DOH) of maize was on 19^{th} September in 2001, while the delayed was on 29^{th} October in 2006. In blackgram, the earliest DOS was on 16^{th} June in 2001, while the delayed was on 8^{th} August in 2002 and 2003. The earliest date of harvest of blackgram was on 10^{th} September in 2003, while the delayed was on 29^{th} October in 2006. Maize and blackgram had a minimum crop growing period of 56 and 34 days in 2003 respectively, while they had a maximum of 123 days in 2006.

Assessment of fertilizer treatments through rainfall and soil moisture variables

The differences in soil moisture observed at sowing and harvest and yield attained by different treatments could be tested based on the standard Analysis of Variance (Gomez and Gomez, 1985). Based on the analysis, a superior treatment for significantly higher soil moisture at sowing and harvest could be identified. Treatment-wise regression models could be calibrated for predicting yield through rainfall received in different months during crop growing period and available soil moisture at sowing and harvest (Draper and Smith, 1998; Maruthi Sankar, 1986). The models could be used for prediction of yield; assessing the effect of monthly rainfall and available soil moisture on yield; and identifying a superior treatment for attaining sustainable yield over years.

The regression model of yield postulated through rainfall (RF), soil moisture at sowing (SMS) and harvest (SMH) variables for each treatment can be given as

Y = ±á ±β1 (Jun RF) ±β2 (Jul RF) ±β3 (Aug RF) ±β4 (Sep RF) ±β5 (SMS) ± β6(SMH) …… (1)

In model (1), á is intercept and β's are regression coefficients of rainfall and soil moisture variables. We can assess regression models based on estimates of coefficient of determination (R^2) and prediction error (Ö) derived for each treatment.

Distribution of soil moisture in different treatments at sowing and harvest

The treatment-wise soil moisture (mm) was recorded from 0–15, 15–30 and 30–45 cm depth at sowing and harvest in maize, blackgram and maize + blackgram blocks based on gravimetric method. The mean and variation (%) of soil

Table 2: Mean and variation of soil moisture at sowing and harvest of crops at Arjia

Treatment	Soil moisture (%) at sowing						Soil moisture (%) at harvest					
	Maize		Blackgram		Maize + blackgram		Maize		Blackgram		Maize + blackgram	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
T1	27.2	4.3	28.1	2.0	28.9	1.9	19.4	13.3	19.4	12.2	20.0	7.0
T2	28.0	2.3	27.5	9.3	29.4	2.2	21.1	5.3	21.2	7.7	20.8	3.5
T3	29.8	2.3	29.2	3.9	30.0	2.0	20.8	6.4	21.8	11.9	21.2	5.0
T4	30.7	4.7	30.0	2.7	31.1	1.8	22.8	7.4	22.4	5.4	21.6	4.5
T5	31.5	2.2	31.6	2.3	31.1	1.9	22.4	5.0	23.7	4.0	20.4	4.9
T6	30.0	2.8	31.4	2.4	30.8	2.0	23.5	8.3	22.4	2.4	21.9	2.6
T7	30.7	2.1	30.9	2.0	31.2	2.0	23.0	4.4	23.0	3.4	22.6	3.6
T8	29.9	1.9	30.8	1.8	30.8	2.1	23.0	3.9	23.6	5.7	21.7	2.0
T9	30.9	1.9	31.5	2.4	30.6	2.1	22.9	2.9	23.3	7.5	23.6	6.4
Mean	29.9	4.8	30.1	5.1	30.4	2.7	22.1	6.1	22.3	6.1	21.5	5.1
CD (0.05)	0.57		0.87		0.24		0.64		0.72		0.80	

T1: Control T2: 50 kg N ha^{-1} (urea) T3: 25 kg N ha^{-1} (urea) T4:25 kg N ha^{-1} (compost)
T5: 15 kg N (compost) + 10 kg N ha^{-1} (urea) T6: 15 kg N (compost) + 20 kg N ha^{-1} (urea)
T7: 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) T8: 15 kg N (green leaf) + 20 kg N ha^{-1} (urea)
T9: 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) CV: Coefficient of variation (%)

moisture in different treatments at sowing and harvest during 1998 to 2006 along with critical difference at $p < 0.05$ level of significance are given in Table 2. The treatments differed significantly for measurements made on soil moisture at sowing and harvest in the three blocks based on F-test.

The mean soil moisture at sowing ranged from 27.2% in control to 31.5% in 15 kg N (compost) + 10 kg N ha^{-1} (urea) under maize block, 27.5% in 50 kg N ha^{-1} (urea) to 31.6% in 15 kg N (compost) + 10 kg N ha^{-1} (urea) under blackgram block and 28.9% in control to 31.2% in 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) under maize + blackgram block. The mean soil moisture at harvest ranged from 19.4% in control to 23.5% in 15 kg N (compost) + 20 kg N ha^{-1} (urea) under maize block, 19.4% in control to 23.7% in 15 kg N (compost) + 10 kg N ha^{-1} (urea) under blackgram block and 20.0% in control to 23.6% in 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) under maize + blackgram block. The soil moisture at harvest had a relatively higher variation compared to soil moisture at sowing in all treatments except 50 kg N ha^{-1} (urea) for soil moisture at sowing under blackgram block.

61.3% for 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) to 65.4% for 15 kg N (compost) + 10 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) treatments under maize + blackgram block. At a market value of maize stover @ Rs.0.6/ kg and blackgram stover @ Rs.0.75/kg, and cost of fertilizer N @ Rs.10.8/kg, 15 kg N (compost) + 20 kg N ha^{-1} (urea) gave a maximum mean net returns of Rs.27069 ha^{-1} with a benefit-cost (BC) ratio of 3.38 under maize block, Rs.17865 ha^{-1} with a BC ratio of 3.44 under blackgram block and Rs.24122 ha^{-1} with a BC ratio of 3.65 under maize + blackgram block. The maize and blackgram biomass yield and maize biomass equivalent yield under maize + blackgram block attained with different treatments along with critical difference values at $p < 0.05$ based on ANOVA are given in Table 3**.** The analysis indicated that there was a significant difference in biomass yields attained by fertilizer treatments under maize, blackgram and maize + blackgram blocks in all seasons.

The fertilizer treatments attained a maximum biomass yield with minimum variation under maize, followed by maize + blackgram and blackgram block. Application of 15 kg N (compost) + 10 kg N ha^{-1} (urea) was superior with a maximum biomass yield under maize and blackgram and maize + blackgram, while control gave lowest yield under all the 3 blocks.

Correlation of crop yield with rainfall and soil moisture variables

Treatment-wise estimates of correlation coefficients of biological yield with rainfall received in June, July, August and September; and soil moisture at sowing and harvest under maize, blackgram and maize + blackgram blocks are given in Table 4. Under maize block, the biomass yield had a significant positive correlation with June rainfall under all treatments except control and 15 kg N (green leaf) + 10 kg N ha^{-1} (urea). It had a significant positive correlation with soil moisture at sowing under control, 25 kg N ha^{-1} (urea) and 15 kg N (compost) + 10 kg N ha^{-1} (urea), while it had a significant negative correlation with soil moisture at harvest under all treatments except 15 kg N (compost) + 10 kg N ha^{-1} (urea), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) and 15 kg N (compost)

Table 3: Mean and variation of biomass yield attained by fertilizer treatments at Arji

Treatment	Mean (kg ha^{-1}) and variation (%) biomass yield of crops					
	Maize block		Black gram block		*Maize + black gram block	
	Mean	CV	Mean	CV	Mean	CV
Control	2690 (9)	48.4	835 (9)	79.9	2467 (9)	62.2
50 kg N ha^{-1} (urea)	3502 (5)	55.0	1056 (6)	80.0	3125 (7)	61.6
25 kg N ha^{-1} (urea)	3116 (8)	51.7	931 (8)	80.0	2848 (8)	62.5
25 kg N ha^{-1} (compost)	3346 (7)	53.7	1018 (7)	78.6	3152 (6)	63.7
15 kg N (compost) + 10 kg N ha^{-1} (urea)	3646 (1)	54.3	1215 (1)	82.6	3449 (1)	65.4
15 kg N (compost) + 20 kg N ha^{-1} (urea)	3588 (2)	58.3	1187 (2)	78.2	3288 (3)	64.7
15 kg N (green leaf) + 10 kg N ha^{-1} (urea)	3551 (3)	53.3	1156 (3)	80.2	3380 (2)	65.4
15 kg N (green leaf) + 20 kg N ha^{-1} (urea)	3512 (4)	55.9	1133 (4)	79.0	3284 (4)	63.9
15 kg N (compost)+ 10 kg N ha^{-1} (green leaf)	3498 (6)	53.9	1063 (5)	77.2	3224 (5)	62.7
Mean	3383	53.7	1066	79.0	2989	61.3
Critical difference ($p < 0.05$)	300		136		293	

* Maize equivalent yield CV: Coefficient of variation (%) Value in parentheses is rank of a treatment

Table 4: Correlation of maize yield with rainfall (RF), soil moisture at sowing (SMS) and harvest (SMH) at Arjia

Variable	T1	T2	T3	T4	T5	T6	T7	T8	T9
Maize block									
Jun-RF	0.49	0.65*	0.61*	0.60*	0.60*	0.65*	0.59	0.66*	0.65*
Jul-RF	0.40	0.45	0.40	0.46	0.46	0.43	0.48	0.44	0.44
Aug-RF	0.38	0.47	0.46	0.46	0.46	0.48	0.46	0.48	0.49
Sep-RF	-0.13	-0.07	-0.10	-0.10	-0.12	-0.06	-0.13	-0.06	-0.07
SMS	0.66*	0.31	0.67*	-0.20	0.67*	0.08	0.59	0.45	0.39
SMH	-0.68*	-0.73*	-0.68*	-0.71*	-0.31	-0.77**	-0.55	-0.69*	-0.40
Black gram block									
Jun-RF	0.20	0.31	0.17	0.23	0.20	0.22	0.30	0.26	0.32
Jul-RF	0.75*	0.74*	0.74*	0.75*	0.73*	0.74*	0.72*	0.74*	0.73*
Aug-RF	0.52	0.58	0.52	0.56	0.50	0.53	0.56	0.57	0.64*
Sep-RF	-0.26	-0.20	-0.28	-0.26	-0.27	-0.28	-0.22	-0.25	-0.21
SMS	0.28	0.27	0.35	0.35	0.38	0.04	0.20	0.34	0.01
SMH	-0.41	-0.49	-0.38	-0.44	-0.29	-0.09	-0.34	-0.41	-0.48
Maize + black gram block									
Jun-RF	0.30	0.41	0.44	0.43	0.43	0.50	0.45	0.49	0.50
Jul-RF	0.62*	0.59	0.57	0.61*	0.58	0.56	0.55	0.56	0.56
Aug-RF	0.32	0.40	0.38	0.41	0.43	0.46	0.40	0.42	0.47
Sep-RF	-0.30	-0.26	-0.26	-0.25	-0.25	-0.22	-0.25	-0.24	-0.20
SMS	0.45	0.29	0.70*	0.61*	0.41	0.70*	0.71*	0.73*	0.31
SMH	-0.25	-0.39	-0.41	-0.44	0.37	-0.08	-0.29	0.02	-0.52

* & ** indicate significance at $p < 0.05$ & $p < 0.01$

T1: Control
T2: 50 kg N ha^{-1} (urea)
T3: 25 kg N ha^{-1} (urea)
T4: 25 kg N ha^{-1} (compost)
T5: 15 kg N (compost) + 10 kg N ha^{-1} (urea)
T6: 15 kg N (compost) + 20 kg N ha^{-1} (urea)
T7: 15 kg N (green leaf) + 10 kg N ha^{-1} (urea)
T8: 15 kg N (green leaf) + 20 kg N ha^{-1} (urea)
T9: 15 kg N (compost) + 10 kg N ha^{-1} (green leaf)

+ 10 kg N ha^{-1} (green leaf). In blackgram block, the biomass yield had a significant positive correlation with July rainfall for all treatments, while the yield of 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) alone had a significant positive

Table 5: Regression coefficients of monthly rainfall (RF), soil moisture at sowing (SMS) and harvest (SMH) for predicting maize yield at Arjia

Variable	T1	T2	T3	T4	T5	T6	T7	T8	T9
Maize block									
Intercept	–10191	–22642	–23607	33769	–60038	–19964	–36059	–24998	–15194
Jun-RF	–1.87	–17.94	–5.19	18.1	–18.21	–13.09	–16.98	–15.4	7.21
Jul-RF	5.78*	–2.43	3.53	12.83	–2.77	0.12	–0.11	–0.92	–0.79
Aug-RF	–1.75	3.36	0.02	–3.25	4.42	1.96	2.95	2.85	3.82
Sep-RF	–4.66	–13.79	–7.31	–0.49	–12.59	–12.99	–12.13	–12.05	–6.49
SMS	712*	2662	1596*	–877	3237	1981	2702*	2892*	1415
SMH	–359*	–2199	–999*	–298	–1643	–1474*	–1832	–2458*	–1127
R^2	0.96*(3)	0.94 (6)	0.98*(1)	0.86 (8)	0.86 (7)	0.95 (4)	0.94 (5)	0.96 (2)	0.62 (9)
Error	465 (2)	867 (4)	383 (1)	1340 (7)	1442(8)	910 (5)	938 (6)	758 (3)	2334 (9)
η	30.8 (6)	36.5 (4)	37.8 (2)	27.7 (8)	30.5 (7)	37.0 (3)	36.1 (5)	38.1 (1)	16.1 (9)
Black gram block									
Intercept	–7467	4844	–624	53	–4905	16965	5121	3097	19863
Jun-RF	–6.92	–2.87	–4.32	–6.64	–8.36	15.14	–5.09	–5.31	3.66
Jul-RF	2.59	6.2**	5.49*	4.79*	5.52	12.26*	3.81	5.86*	6.89
Aug-RF	0.70	–0.05	–0.16	0.44	0.74	–2.79	1.45	0.35	–0.09
Sep-RF	–3.18	–0.88	–1.39	–2.3	–2.72	3.53	–2.65	–1.86	0.61
SMS	439	75	161	351	596	–1350	362	293	–591
SMH	–212	–329*	–181	–453*	–564	1041	–689	–505*	–85
R^2	0.83 (8)	0.98*(1)	0.95 (4)	0.97*(2)	0.85 (7)	0.92 (5)	0.73 (9)	0.95 (3)	0.88 (6)
Error	552 (6)	224 (1)	324 (3)	275 (2)	785 (8)	534 (5)	959 (9)	389 (4)	562 (7)
η	8.6 (8)	25.4 (1)	18.5 (5)	22.7 (3)	13.1 (7)	19.9 (4)	6.0 (9)	22.7 (2)	15.3 (6)
Maize + black gram block									
Intercept	–33834	15135	–37752	41775	–40379	–11407	87348	–15877	5680
Jun-RF	–9.86	–6.53	–10.98	2.14	7.36	11.19	16.08	16.74	0.20
Jul-RF	1.37	11.58*	4.64	16.49*	4.19	4.14	20.5*	6.25	12.06*
Aug-RF	1.36	–0.32	0.90	–0.61	1.87	–1.14	1.28	–6.34	0.27
Sep-RF	–11.72	–4.44	–9.98	1.50	–11.55	–12.93	11.10	–17.89	–1.80
SMS	1752	1685	2085	–37	1036	2655	–664	2719	815
SMH	–676	–3047*	–1030	–1913*	512	1589	–3097	3602	–1273*
R^2	0.59(8)	0.97*(3)	0.90(5)	0.98*(2)	0.54(9)	0.79(7)	0.95(4)	0.88(6)	0.98*(1)
Error	1971(8)	654 (3)	1145(5)	477 (1)	3072(9)	1951(7)	1004(4)	1414(6)	539 (2)
η	7.1 (8)	35.4 (3)	24.4 (6)	38.3 (2)	5.4 (9)	19.1 (7)	34.0 (4)	26.8 (5)	38.4 (1)

Values in parentheses are ranks assigned to treatments * indicates significance at $p < 0.05$
η: Sustainability yield index
T1: Control T2: 50 kg N ha^{-1} (urea) T3: 25 kg N ha^{-1} (urea)
T4: 25 kg N ha^{-1} (compost) T5: 15 kg N (compost) + 10 kg N ha^{-1} (urea)
T6: 15 kg N (compost) + 20 kg N ha^{-1} (urea) T7: 15 kg N (green leaf) + 10 kg N ha^{-1} (urea)
T8: 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) T9: 15 kg N (compost) + 10 kg N ha^{-1} (green leaf)

correlation with rainfall received in August. In maize + blackgram block, the maize equivalent biomass yield of control and 25 kg N ha^{-1} (compost) had a significant positive correlation with July rainfall, while it had a significant positive correlation with soil moisture at sowing in 25 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost), 15 kg N (compost) + 20 kg N ha^{-1} (urea), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea).

Regression models of yield through rainfall and soil moisture variables

Regression models of biomass yield through monthly rainfall, soil moisture at sowing and harvest are given in Table 5 for each treatment. The models of control, 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (urea), 15 kg N (compost) + 20 kg N ha^{-1} (urea), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) under maize block; 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost), 15 kg N (compost) + 20 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) under blackgram block; and 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) and 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) under maize + blackgram block had a significant yield predictability through rainfall and soil moisture variables. The R^2 of biomass yield ranged from 0.62

for 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) to 0.98 for 25 kg N ha^{-1} (urea) under maize; 0.73 for 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) to 0.98 for 50 kg N ha^{-1} (urea) under blackgram; and 0.54 for 15 kg N (compost) + 10 kg N ha^{-1} (urea) to 0.98 for 25 kg N ha^{-1} (compost) and 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) under maize + blackgram block. The prediction error of biomass yield based on models ranged from 383 kg ha^{-1} for 25 kg N ha^{-1} (urea) to 2334 kg ha^{-1} for 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) under maize; 224 kg ha^{-1} for 50 kg N ha^{-1} (urea) to 959 kg ha^{-1} for 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) under blackgram; and 477 kg ha^{-1} for 25 kg N ha^{-1} (compost) to 3072 kg ha^{-1} for 15 kg N (compost) + 10 kg N ha^{-1} (urea) under maize + blackgram block.

The regression coefficients indicated that June rainfall had a negative influence on biomass yield of maize and blackgram in the respective blocks, while it had a positive influence on maize equivalent yield under maize + blackgram block. The July rainfall had a negative influence on biomass yield in maize block, while it had a positive influence on biomass yield in blackgram block and maize equivalent yield under maize + blackgram block. August rainfall had a positive influence, while September rainfall had a negative influence on the biomass yield of maize and blackgram under respective blocks and maize equivalent yield under maize + blackgram block. However, July rainfall had a significant effect on biomass yield of control under maize block; 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost), 15 kg N (compost) + 20 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) under blackgram block; and 25 kg N ha^{-1} (compost), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) and 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) under maize + blackgram block.

The soil moisture at sowing had a positive influence on biomass yield attained by all treatments except 25 kg N ha^{-1} (compost) under maize; 15 kg N (compost) + 20 kg N ha^{-1} (urea) and 15 kg N (compost) + 10 kg N ha^{-1} (green leaf) under blackgram; and 25 kg N ha^{-1} (compost) and 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) under maize + blackgram block. The soil moisture at harvest had a negative influence on biomass yield attained by all treatments under maize; except 15 kg N (compost) + 20 kg N ha^{-1} (urea) under blackgram; and except 15 kg N (compost) + 10 kg N ha^{-1} (urea), 15 kg N (compost) + 20 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) under maize + blackgram block based on regression models. However, soil moisture at sowing had a significant positive effect on biomass yield of maize attained by control, 25 kg N ha^{-1} (urea), 15 kg N (green leaf) + 10 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea); while soil moisture at harvest had a significant negative effect on yield attained by control, 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (urea), 15 kg N (compost) + 20 kg N ha^{-1} (urea) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea) under maize block. Under blackgram block, the soil moisture at harvest had a significant negative effect on biomass yield of blackgram attained by 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost) and 15 kg N (green leaf) + 20 kg N ha^{-1} (urea). Under maize + blackgram block, the soil moisture at harvest had a significant negative effect on the maize equivalent yield attained by 50 kg N ha^{-1} (urea), 25 kg N ha^{-1} (compost) and 15 kg N (compost) + 10 kg N ha^{-1} (green leaf).

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Received: December 2009; Accepted: March 2010