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Performance of different weed management treatments on heat use efficiency of chickpea crop (*Cicer arietinum*) under rainfed conditions of Jammu

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ABSTRACT

An experiment was undertaken during *rabi* 2008-09 and 2009-10 at Agronomy Research Farm, PRSS, Samba, SKUAST-J to find out the heat use efficiency of chickpea (*Cicer arietinum* L.) crop with different weed control treatments, viz. T_1: weedy check; T_2: Hand-weeding (HW) at 25-30 and 50-55 DAS; T_3: Quizalofop-ethyl 40 g/ha at 20 DAS; T_4: Quizalofop-ethyl 40 g/ha at 30 DAS; T_5: Quizalofop-ethyl 50 g/ha at 20 DAS; T_6: Quizalofop-ethyl 50 g/ha at 30 DAS; T_7: Imazethapyr 25 g/ha at 20 DAS; T_8: Imazethapyr 25 g/ha at 30 DAS; T_9: Imazethapyr 40 g/ha at 20 DAS; T_{10}: Imazethapyr 40 g/ha at 30 DAS; T_{11}: Chlorimuron ethyl 4 g/ha at 20 DAS and T_{12}: Chlorimuron ethyl 4 g/ha at 30 DAS evaluated in randomized block design with three replications under rainfed situations. Chickpea is a thermo-sensitive winter season crop. Heat use efficiency was computed at one month interval after sowing. The results revealed that heat use efficiency was found maximum at 90 DAS in chickpea crop. The heat use efficiency was found highest under hand-weeding at 25-30 and 50-50 DAS, however, the lowest values were found when herbicide Chlorimuron was used @ 4 g/ha at 30 DAS. The dry matter and seed yield are significantly differed among different weed control treatments. The heat use efficiency was found linearly ($R^2 = 0.70$) related with dry matter accumulation at different days after sowing. The grain yield and biological yield heat use efficiency was found 0.33 and 0.90 kg/ha °C/day, respectively. The dry matter was found to be directly related to seed yield of chickpea crop with $R^2 = 0.98$.

Key words: Chickpea, Heat use efficiency, Rainfed, Weed control

Chickpea (*Cicer arietinum* L.) is cultivated globally with an area of 12.03 million hectare adding 9.24 million tonnes of grains annually to the world food basket with an average productivity 768 kg/ha. It is the most important pulse crop of India sharing 29.7 and 38% of total area and production of total pulses, respectively (Chand *et al*. 2010). In Jammu and Kashmir state, chickpea is grown in about 4300 hectare area with a production of 2550 tonnes and productivity of 593 kg/ha (Singh *et al*. 2010). In kandi areas of Jammu region, farmers do not follow chemical weed control in pulses, except for 5-10 per cent farmers who use pre-emergence herbicides followed by one or two hand-weedings. But, to bridge the gap between actual and potential levels of production of pulses, an effective weed control measure has to be found out so as to reduce the drudgery of farmers and also to save time (Gupta *et al*. 2012).

Temperature is the prime weather variable which affects plant life. Agronomic application of temperature effect on plants is the heat unit concept which had been variously applied to correlate phenological development in crops to predict maturity dates (Nuttonson 1955, Gilmore and Rodgers 1958). The growth and productivity of crops depends on physical environments in a particular ecosystem. It is therefore, essential to have knowledge of exact duration of development phases in a particular environment and their association with yield determinants for achieving high yield (Singh *et al*. 2003). The concept of growing degree days is based on the concept that real time to attain a phenological stage is linearly related to temperature in the range between base temperature and optimum temperature (Monteith 1981). Apart from this, heat use efficiency (HUE), i.e efficiency of utilization of heat in terms of dry matter accumulation is an important aspect, which has practical utility as reported for soybean and pigeonpea (Balakrishanan and Natarajaratnam 1986). The total heat energy available to any crop is never completely converted to dry matter under even the most favourable agroclimatic conditions. Efficiency of conversion of heat energy into dry matter depends upon genetic factors, sowing time and crop type (Rao *et al.* 1999).

At optimum thermal environment, morphological and development changes in plant will take place at the most rapid rate. Heat exchanges, at the plants' surface are in the

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form of adsorption of heat and heat loss by conduction, transpiration and irradiation influencing the heat balance at the surface to provide net available heat assessed in terms of temperature index. Therefore, accumulated effective temperature has been used as a practical and functional agroclimatic index regarding the heat requirements of plants in addition to quantification of heat resources at place. Temperature, as an index of thermal environment strongly influence the development rate in terms of cardinal temperature levels of threshold, optimum and inversion or upper threshold points for all living organisms including plants. Therefore, plants' response to environment not only involves in the direct modification of the organism (increase of size or mass), but also sets limits to the adaptability of the organism, and provide a thermal environment force in plants to trigger a set a sequential steps in organisms' life cycle.

MATERIALS AND METHODS

A field experiment was conducted at Agronomy Research Farm of Pulse Research Sub-Station (PRSS), Samba, (J&K) during *rabi* 2008-09 and 2009-10. It is located at an elevation of 332 m above msl having latitude of 32°39' N and longitude 74°53' E. The soil of the experimental site was sandy loam, having 0.32% organic carbon, available nitrogen 185 kg/ha, phosphorus 21.2 kg/ha and potassium 286 kg/ha. Twelve weed control treatments, viz T_1: weedy check (control); T_2: Hand-weeding (HW) at 25-30 and 50-55 DAS; T_3: Quizalofop-ethyl 40 g/ha at 20 DAS; T_4: Quizalofop-ethyl 40 g/ha at 30 DAS; T_5: Quizalofop-ethyl 50 g/ha at 20 DAS; T_6: Quizalofop-ethyl 50 g/ha at 30 DAS; T_7: Imazethapyr 25 g/ha at 20 DAS; T_8: Imazethapyr 25 g/ha at 30 DAS; T_9: Imazethapyr 40 g/ha at 20 DAS; T_{10}: Imazethapyr 40 g/ha at 30 DAS; T_{11}: Chlorimuron ethyl 4 g/ha at 20 DAS and T_{12}: Chlorimuron ethyl 4 g/ha at 30 DAS were arranged in randomized block design with 3 replications. The chickpea variety GNG-469 was sown on 27 November 2008 and 10 December 2009 and harvested on 20 April 2009 and 6 April 2010 during *rabi* 2008-09 and 2009-10, respectively. The crop was raised using appropriate package of practices for *kandi* belt of Jammu region. Hand weeding was done at the proper time and to avoid the rainfall or some other unavoidable circumstances the range was set (25-30 or 50-55 DAS). Different herbicidal application was done as per the treatments. Recommended dose of fertilizers (20 kg N and 50 kg P/ha) was applied to the chickpea crop at the time of sowing through diammonium phosphate (DAP). The rainfall received during the cropping seasons was 164.9 and 87.6 mm in *rabi* 2008-09 and 2009-10, respectively. Weed population and dry-weight was taken at 70 DAS and maturity stage of chickpea crop using quadrate method. The weed population was then counted into different weed flora and weighed by transforming into g/m^2 by using the appropriate formula. The dry matter production of chickpea crop was determined by uprooting 5 plants randomly from each plot at different days after sowing. The plants were dried in an electric oven at ±65°C till the constant dry-weight was obtained; and was then converted into g/m^2. The weather data were recorded from observatory of PRSS, Samba. Agrometeorological indices were calculated at different stages by using appropriate formulae.

Accumulated heat unit (ΣHU): The accumulated heat unit were calculated by adopting the formula given by Nuttonson (1955):

$$HU = \Sigma_a^b \frac{[T\ max + T\ min\ ] - T_b}{2}$$

where, T max, Maximum temperature (°C) during a day; T min, Minimum temperature (°C) during a day; T_b , Base temperature (5°C) of chickpea crop under sub tropical condition; a Starting date of phenophase of interest, b Ending date of phenophase of interest.

Heat use efficiency (HUE): HUE is the ratio of dry matter (g/m^2) to the accumulated heat unit to attain the phenophases.

$$HUE\ (g/m^2/^oC/day) = \frac{Dry\ matter\ (g/m^2)}{Accumulated\ heat\ unit\ (^\circ C\ days)}$$

Weed control efficiency (WCE) was calculated by using the following formula (Mani *et al.* 1973):

$$WCE = \frac{WDC - WDT}{WDC} \times 100$$

where: WCE, Weed control efficiency; WDC, Weed dry matter in control; WDT, Weed dry matter in treatment.

The other ratios were calculated by using the formula as suggested by Devasenapathy *et al.* (2008):

$$\text{Crop Resistance Index (CRI)} = \frac{\text{Dry matter prod by the crop in the treatment plot}}{\text{Dry matter prod in control}} \times \frac{\text{Dry matter prod of weed in control plot}}{\text{Dry matter prod weed in treatment plot}}$$

$$\text{Weed Management Index (WMI)} = \frac{\text{Per cent yield over control}}{\text{Per cent control of weed}}$$

The Statistical analysis was done by using SPSS16 software.

RESULTS AND DISCUSSION

Effect on weeds

The experiment field was invaded both grass type and broad leaf weeds and the per cent distribution was about 35 and 65 per cent, respectively in the seasons of study and the major species of weeds were *Lolium* spp., *Daucas carota*, *Anagallis arvensis*, *Cynodon dactylon*, *Sorghum halepense*, *Chenopodium album*, *Amaranthus* spp., *Convolvulus arvensis, Ipomea* spp., *Tribulis terrestris, Euphorbia* spp., *Circium arvensis,* etc. The highest weed density (14.3 and 15.3 no/m^2) and weed dry matter production (6.54 and 7.04 g/m^2) at 70 DAS and harvest were recorded in weedy check plots (Table 1). All the treatment combinations of weed control resulted in significantly lower weed density and dry matter of weeds as compared to the control plots. The lowest density and dry matter of weeds at 70 DAS and harvest were observed under HW at 25-30 and 50-55 DAS resulting in highest weed control efficiency (WCE) to the tune of 94.3 and 87.2 per cent, respectively (Table 1). Singh and Chandel (1995) also reported the higher WCE with two hand weedings. Statistically similar results with respect to weed density and weed dry-weight were obtained with post-emergence (POE) application of imazethapyr 40 g/ha (30 DAS) and imazethypr 25 g/ha (30 DAS) at 70 DAS and harvest with the corresponding values of 4.1, 4.1 and 5.2, 5.4 no/m^2 and 3.24, 3.36 and 3.68, 3.78 g/m^2, respectively being the lowest among all the weed control treatments (Table 1). Data further revealed that other herbicides quizalofop-ethyl and chlorimuron also reduced the density and dry matter of weeds in different proportions but were not statistically at par with hand weeding or imazethapyr treatments. The results are in conformity with the findings of Ceylan and Toker (2006) who reported a limited weed control by quizalofop-ethyl among various herbicides. Vyas and Jain (2003) also observed greater values of WCE, seed yield with the application of imazathypr in comparison to quizalofop-ethyl in soybean crop. Maximum WCE was registered in hand-weedings treatment followed by POE imazethapyr 40 g/ha at 30 DAS and imazathypr 25 g/ha at 30 DAS which was 76.1 and 73.9 and 73.3 and 71.9 per cent at 70 DAS and harvest, respectively (Table 1). The results were confirmed by the findings of Kantar *et al.* (1999) who obtained 84.6 per cent control of weed biomass with application of imazathypr. Higher efficacy and long lasting effects of imazethapyr in reducing weed dry matter (upto 85%); primarily appeared due to broad-spectrum activity of this herbicide particularly on established plants of both narrow and broad leaf weeds and its greater efficiency to retard cell division of meristems as a result of which weeds died rapidly. Papierniks *et al.* (2003) also recommended use of imazethapyr chemical in legumes that inhibit acetohydroxy acid synthase and the synthesis of branched chain amino acids. Two doses (40 and 50 g/ha) of post emergence herbicide quizalofop-ethyl at 20 and 30 DAS gave almost statistically at par results with each other for total weed density and dry matter yield at 70 DAS and harvest. However, the same treatment combinations registered weed control efficiency values in the range of 40.4 to 55.2%. The results are combined by the findings of

Table 1 Effect of different herbicides on weed density, weed dry matter, weeds control efficiency, crop resistance index and weed management index (pooled data over two years)

Treatment	Total weeds density (no/m^2)		Dry matter yield (g/m^2)		Weed control efficiency (%)		Crop resistance index	Weed management index
	70 DAS	At Harvest	70 DAS	At Harvest	70 DAS	At Harvest		
Weedy Check	14.3 (204)	15.3 (233)	6.54 (42.6)	7.04 (49.4)				
HW at 25-30 & 50-55 DAS	3.9 (15)	4.9 (25)	1.66 (2.4)	2.59 (6.3)	94.3	87.2	12.8	0.68
Quizalofop-ethyl 40 g/ha at 20 DAS	5.5 (31)	6.7 (45)	5.07 (25.4)	5.37 (28.6)	40.4	42.7	1.9	0.28
Quizalofop-ethyl 40 g/ha at 30 DAS	5.1 (26)	6.2 (39)	4.76 (22.3)	4.94 (24.0)	47.7	51.4	2.5	0.34
Quizalofop-ethyl 50 g/ha at 20 DAS	5.1 (26)	6.0 (36)	4.66 (21.4)	4.85 (23.2)	49.8	53.0	2.7	0.45
Quizalofop-ethyl 50 g/ha at 30 DAS	5.7 (32)	6.7 (45)	4.40 (19.2)	4.84 (23.1)	55.2	53.2	1.3	0.56
Imazethapyr 25 g/ha at 20 DAS	4.4 (19)	5.9 (33)	3.71 (13.4)	4.09 (16.4)	68.9	66.8	4.2	0.55
Imazethapyr 25 g/ha at 30 DAS	4.1 (17)	5.4 (29)	3.36 (11.1)	3.78 (13.9)	73.9	71.9	5.4	0.68
Imazethapyr 40 g/ha at 20 DAS	4.6 (21)	5.1 (26)	3.51 (12.2)	3.94 (15.2)	71.4	69.2	4.7	0.62
Imazethapyr 40 g/ha at 30 DAS	4.1 (16)	5.2 (27)	3.24 (10.2)	3.68 (13.2)	76.1	73.3	5.9	0.75
Chlorimuron-ethyl 4 g/ha at 20 DAS	8.5 (72)	9.3 (87)	5.88 (34.2)	6.45 (41.2)	19.7	16.6	1.3	0.43
Chlorimuron-ethyl 4 g/ha at 30 DAS	9.0 (81)	9.5 (90)	6.06 (36.4)	6.75 (45.2)	14.6	8.5	1.2	0.59
CD (P=0.05)	0.75	1.03	0.99	0.21				
SEm±	0.25	0.49	0.34	0.07				

Figures in parentheses are means of original values and outside are means of transformed ($\sqrt{x+0.5}$) values. HW, Hand weeding; DAS, days after sowing

Ceylan and Toker (2006) where quizalofop provided limited weed control in comparison to other post-emergence herbicides. Vyas and Jain (2003) also registered WCE of quizalofop-ethyl in the range of 61-76% in soybean crop. Vidrine *et al.* (1995) reported similar results for quizalofop-ethyl and quizalofop-tefuryl in soybean crop. POE application of chlorimuron 4 g/ha at 20 and 30 DAS recorded maximum values of total weed density (72 and 81 no/m^2) and dry matter yield of weeds (34.2 and 36.4 g/m^2) as compared to all other treatment combinations except control. A similar trend was observed for the values of total weed density and weed dry matter at harvest also.

Dry matter accumulation

The dry matter accumulation in chickpea crop increased with the advancement of crop and it was observed maximum at the time of harvest in chickpea crop (Table 2). The dry matter accumulation differed significantly among different weed control treatments at different days after sowing (DAS). Hand weeding twice at 25-30 and 50-55 DAS resulted maximum dry matter at harvest (179.2 g/m^2) followed by imazethapyr 40 g/ha at 30 DAS (173.7 g/m^2), imazethapyr 25 g/ha at 30 DAS (167.7 g/m^2), imazethapyr 40 g/ha at 20 DAS (160.5 g/m^2), imazethapyr 25 g/ha at 20 DAS (154.9 g/m^2), quizalofop-ethyl 50 g/ha at 30 DAS (147.3 g/m^2), quizalofop-ethyl 50 g/ha at 20 DAS (139.6 g/m^2), quizalofop-ethyl 40 g/ha at 30 DAS (132.4 g/m^2), quizalofop-ethyl 40 g/ha at 20 DAS (125.1 g/m^2), chlorimuron-ethyl 4 g/ha at 20 DAS (122.6 g/m^2), chlorimuron-ethyl 4 g/ha at 30 DAS (118.5 g/m^2) and weedy check (108.8 g/m^2) in chickpea crop (Table 2); which showed that the manual weeding at 25-30 and 50-55 DAS was the best among different chemical weed control in chickpea crop which produced higher dry matter. Higher efficacy and long lasting effects of imazethapyr in reducing weed dry matter (up to 85 per cent) might be primarily appeared due to broad-spectrum activity of herbicide particularly on established plants of both narrow and broad leaf weeds and its greater efficiency to retard cell division of meristems as a result of which weeds died rapidly (Kantar *et al.* 1999). Gupta *et al.* (2012) also recorded similar results in chickpea crop under rainfed conditions.

Heat use efficiency

The values of HUE showed varied trends at different time intervals during both the years. The mean heat use efficiency was found 0.08, 0.22, 0.22, 0.20 and 0.30 g/m^2/°C/day at 30, 60, 90, 120 DAS and at harvest respectively. Maximum heat use efficiency was found at harvest of chickpea crop while minimum at 30 DAS; however, the values of HUE at 60, 90 and 120 DAS were almost similar. The treatment hand weeding at 25-30 and 50-55 DAS recorded highest; while weedy check treatment showed the lowest values of HUE in chickpea crop at about all the time intervals (Table 3).

Heat use efficiency recorded at an interval of 30 DAS in chickpea crop revealed that it was found maximum in HWs at 25-30 and 50-55 DAS (T_2) and was followed by about similar values of HUE obtained with the treatments imazethapyr 25 g/ha at 30 DAS and imazethapyr 40 g/ha at 30 DAS at all the time intervals including at harvest, which showed that weeds affected the dry matter accumulation in chickpea crop due to difference in dry matter among different weed control treatments. HUE increased with age of crop and recorded highest at 90 DAS (peak flowering) of chickpea crop due to maximum crop canopy. The minimum values of HUE were observed in weedy check (control) which was due to exhaustion of nutrients by weeds and less dry matter accumulation in chickpea crop (Table 3). On the same lines, maximum grain and biological HUE values (0.41 and 1.12 g/m^2/°C/day) were found in the treatment HWs at 25-30 and 50-55 DAS and was followed by about similar values of HUE obtained with the treatments imazethapyr 25 g/ha at 30 DAS and imazethapyr 40 g/ha at 30 DAS (Table 3).

Table 2 Dry matter accumulation (g/m^2) as affected by different weed control treatments (pooled data over two years)

Treatment	Dry matter accumulation (g/m^2)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Weedy check	17.5	36.4	59.9	85.0	108.8
HW at 25-30 & 50-55 DAS	28.7	59.5	97.8	138.8	179.2
Quizalofop-ethyl 40 g/ha at 20 DAS	20.1	41.6	68.4	96.9	125.1
Quizalofop-ethyl 40 g/ha at 30 DAS	21.4	44.1	72.2	102.8	132.4
Quizalofop-ethyl 50 g/ha at 20 DAS	22.5	46.3	76.2	108.3	139.6
Quizalofop-ethyl 50 g/ha at 30 DAS	23.5	49.1	80.5	114.2	147.3
Imazethapyr 25 g/ha at 20 DAS	24.7	51.6	84.7	120.1	154.9
Imazethapyr 25 g/ha at 30 DAS	26.8	55.8	91.5	130.1	167.7
Imazethapyr 40 g/ha at 20 DAS	25.7	53.3	87.7	124.4	160.5
Imazethapyr 40 g/ha at 30 DAS	27.9	57.8	94.9	134.5	173.7
Chlorimuron-ethyl 4 g/ha at 20 DAS	19.5	40.8	66.9	95.1	122.6
Chlorimuron-ethyl 4 g/ha at 30 DAS	18.9	39.4	64.7	91.9	118.5
CD ($P=0.05$)	1.06	1.33	11.03	14.19	3.84
SEm±	0.36	0.45	3.74	4.81	1.30

Table 3 Grain, biological yield and heat use efficiency (g/m^2/^{0}C/ day) of chickpea crop as affected by different weed control treatments

Treatment	Heat-use efficiency (g/m^2/^{o}C/day)					Grain yield (kg/ha)	Biological yield (kg/ha)	Heat-use efficiency (g/m^2/^{0}C/ day)	
	30 DAS	60 DAS	90 DAS	120 DAS	At Harvest			Grain yield	Biological yield
Weedy check	0.065	0.165	0.165	0.15	0.22	404.4	1 087.7	0.26	0.68
HW at 25-30 & 50-55 DAS	0.105	0.27	0.265	0.25	0.365	660.1	1 791.8	0.41	1.12
Quizalofop-ethyl 40 g/ha at 20 DAS	0.075	0.185	0.185	0.17	0.255	463.6	1 251.3	0.29	0.78
Quizalofop-ethyl 40 g/ha at 30 DAS	0.08	0.195	0.195	0.18	0.265	487.1	1 324.1	0.31	0.83
Quizalofop-ethyl 50 g/ha at 20 DAS	0.08	0.21	0.21	0.19	0.285	514.2	1 396.0	0.32	0.88
Quizalofop-ethyl 50 g/ha at 30 DAS	0.09	0.22	0.22	0.20	0.30	538.3	1 472.9	0.34	0.92
Imazethapyr 25 g/ha at 20 DAS	0.09	0.23	0.23	0.215	0.31	566.0	1 549.6	0.36	0.97
Imazethapyr 25 g/ha at 30 DAS	0.10	0.25	0.25	0.23	0.34	618.9	1 676.4	0.39	1.05
Imazethapyr 40 g/ha at 20 DAS	0.09	0.24	0.24	0.22	0.325	590.9	1 605.5	0.37	1.00
Imazethapyr 40 g/ha at 30 DAS	0.10	0.26	0.255	0.24	0.35	643.2	1 737.2	0.39	1.09
Chlorimuron-ethyl 4 g/ha at 20 DAS	0.07	0.185	0.185	0.17	0.25	443.7	1 225.6	0.35	0.77
Chlorimuron-ethyl 4 g/ha at 20 DAS	0.07	0.175	0.175	0.165	0.24	435.3	1 184.8	0.28	0.74
Mean	0.08	0.215	0.215	0.20	0.295	530.5	1 441.9	0.30	0.90
SD (±)	0.01	0.03	0.03	0.03	0.05	82.4	222.6	0.0	0.1

Table 4 Accumulated heat units and heat use efficiency of chickpea at different days after sowing

Days after sowing (DAS)	Accumulated Heat Units		Heat use efficiency	
	2008-09	2009-10	2008-09	2009-10
30	326.8	235.6	0.07	0.09
60	559.1	449.0	0.22	0.21
90	884.0	837.3	0.25	0.18
120	1344.6	1431.0	0.21	0.19
At Harvest	1791.7	1500.0	0.34	0.24

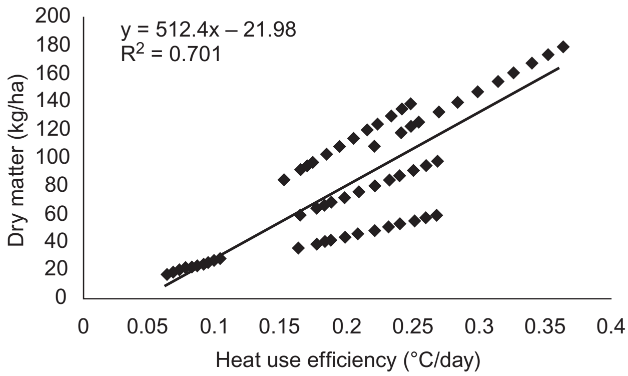

Fig 1 Relationship between heat use efficiency and dry matter of chickpea crop

Thermal heat unit to the tune of 1791.7 and 1500.0 ºC days were taken by chickpea crop during 2008-09 and 2009-10 from sowing to maturity, respectively. It increased with the increase in number of days after sowing**.** The heat use efficiency recorded during 2008-09 and 2009-10 were 0.07, 0.22, 0.25, 0.21 and 0.34 and 0.09, 0.21, 0.18, 0.19 and 0.24 g/m^2/ºC/day at 30, 60, 90, 120 and at harvest, respectively (Table 4).

Grain yield and biomass accumulation

Mean grain yield was recorded 530±82.4 kg/ha, while mean biological yield found 1441.9±222.6 kg/ha. The grain and biological yield was found higher (50.1 and 139.6 kg/ ha) during 2008-09 than 2009-10. This was attributed to more heat unit used for synthesis of biomass which contributed to more grain yield in chickpea crop during

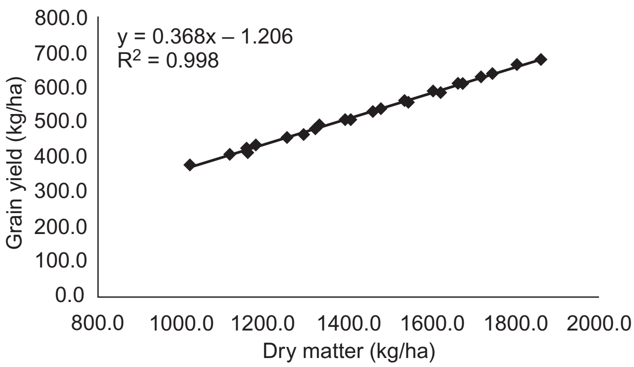

Fig 2 Relationship between dry matter and grain yield of chickpea crop

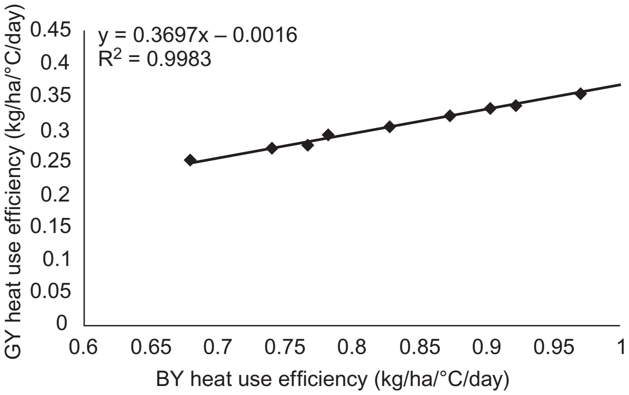

Fig 3 Relationship between biological yield HUE and grain yield heat use efficiency of chickpea crop

rabi 2008-09 as compared to 2009-10. The mean grain yield and biomass recorded 660.1, 643.2, 618.9, 590.9, 566.0, 538.3, 514.2, 487.1, 463.6, 443.7, 435.3, 404.4 kg/ha and 1791.8, 1737.2, 1676.4, 1605.5, 1549.6 1472.9, 1396.0, 1324.1, 1251.3, 1225.6, 1184.8, 1087.7 kg/ha among T_2, T_{10}, T_8, T_9, T_7, T_6, T_5, T_4, T_3, T_{11}, T_{12} and T_1 treatments, respectively; which showed that hand weeding at 25-30 and 50-55 DAS found the most effective weed control treatment among all the other treatment combinations which increased biomass accumulation, improved grain yield in chickpea crop under *kandi* belt of Jammu region (Table 3).

Relationship between of heat use efficiency with crop parameters

Dry matter accumulation in chickpea crop was linearly related to heat use efficiency with an accuracy of 70 per cent. It showed that with the increase in heat use efficiency increased the dry matter accumulation in different weed control treatments (Fig 1). Dry matter accumulation was directly related with the grain yield of chickpea crop in kandi belt of Jammu region. The rate of dry matter converted into grain yield was 0.37 kg/ha with an accuracy of 99 per cent (Fig 2).

Biological yield heat use efficiency (BYHUE) was directly co-related with grain yield heat use efficiency (GYHUE) of chickpea crop with R^2 value of 0.99 which showed that the BYHUE increased with an increase in GYHUE of crop (Fig 3). The findings are in the close conformity with the results of Kour *et al.* (2004) in wheat crop.

CONCLUSION

The hand weeding at 25-30 and 50-55 DAS were found best among all other weed control treatments, which improved the heat use efficiency of chickpea crop, and contributed to more biomass production and ultimately gave more seed yield in *kandi* belt of Jammu region.

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