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Weed management through herbicides in pearl millet (*Pennisetum glaucum* L.) in UKP command area

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Abstract
A field experiment was conducted at College of Agriculture, Bheemarayanagudi during *kharif*, 2023 to study the effect of different herbicides on growth and yield of pearl millet. The experiment was laid in RCBD with eight treatments which were replicated thrice. The results revealed that Atrazine 50% WP as PE @ 500 g *a.i* ha^{-1} *fb* intercultivation at 30-40 DAS recorded significantly higher growth parameters *viz*., plant height, number of tillers, leaf area, leaf area index, total dry matter production and its accumulation in different plant parts. Further, it was found on par with atrazine 50% WP as PE @ 500 g *a.i* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS and atrazine 50% WP as PE @ 500 g *a.i* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i* ha^{-1} as PoE at 20-25 DAS.

Keywords: Pearl millet, weed management, herbicides

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is most widely grown staple food for majority of poor and small farmers in Asia and Africa. It is also consumed as feed and fodder for livestock. It can be grown on light textured soil under low moisture conditions as a sole crop in arid and semi-arid regions because of its drought tolerance capacity (Andrews and Kumar, 1996) [1].

Pearl millet is also known as the "Powerhouse of Nutrition" as it consists of most of the important nutrients in good quantity and quality that is required for maintaining healthy life. It has higher contents of macronutrients and micronutrients such as iron, zinc, calcium, magnesium, copper, manganese, phosphorus, folic acid and riboflavin. It is a rich source of unsaturated fatty acids (75%). Nutritional value of pearl millet is better in comparison to wheat, rice, maize and sorghum. It is a good source of energy, carbohydrate, fat (5-7%), ash, dietary fibre (1.2 g 100 g^{-1}), α-amylase activity, quality protein (9-13%), vitamin A and B minerals (2.3 mg 100 g^{-1}), antioxidants such as ferulic acid and coumaric acids with better fat digestibility.

Pearl millet accounts for almost half of the global millet production. It is the sixth most important cereal crop in the world next to maize, rice, wheat, barley and sorghum. In India, pearl millet is the fourth most widely cultivated food crop after rice, wheat and maize. It occupies an area of 7.65 million ha with an average production of 10.61 million tonnes and productivity of 1420 kg ha^{-1} (Anon., 2024) [2]. The major pearl millet growing states are Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana contributing 90% of total national production. In Karnataka, it occupies an area of 0.22 million ha with an average production of 0.27 million tonnes and productivity of 1241 kg ha^{-1} (Anon., 2024a) [3].

The low productivity of pearl millet is due to an array of biotic and abiotic factors. One of the major constraints in pearl millet production is weed infestation. Weeds compete with the crop plants for the essentials of growth, interfere with the utilization of land and water resources and thus, adversely affect crop production. Weeds deplete 30-40% of applied nutrients from soil and compete with the crop plants for soil moisture and sunlight too (Ram *et al.*, 2005) [16]. Keeping the crop weed-free throughout the crop season is a labour and cost-intensive affair. Hand-weeding is laborious, difficult to execute under frequent intermittent rains, cumbersome and time consuming besides being costly and economically not feasible in today's intensive

agriculture (Sharma and Jain, 2003) [19].

Use of herbicide is the best option to reduce the weed menace during early stages of crop growth. Atrazine is a selective herbicide which is well known and being extensively used in pearl millet grown during rainy season in the country (Das *et al*., 2013) [6]. At present, weeds are controlled by hand weeding twice at 25 and 45 days after sowing and hoeing. However, due to continuous rains during monsoon season as well as irrigating in command areas, it becomes difficult for manual weeding at right time. The pre emergent herbicides are effective only for about initial 30 days and thereafter weeds may threat pearl millet. Sometimes due to unavoidable circumstances, it is not possible to spray pre emergent herbicides and later on it becomes very difficult to control the weeds manually. Under such circumstances, the best possible means to control new flush of weeds are through use of post emergent herbicides (Guriqbal Singh and Sekhon, 2013) [10]. The use of chemical along with manual weeding or intercultivation is the best option for effective weed management (Girase *et al*., 2017) [9] as neither herbicides nor mechanical cultivation alone are adequate for consistent and acceptable weed control.

With the discovery of synthetic herbicides in the early 1940s, there was a shift in control methods towards high input and target-oriented ones. Although the pre emergent application of herbicides found to be effective in controlling weeds, their usage is not only difficult but also can cause crop injury and effect environment because of higher doses used. Ecological problems emanating from the use of higher dose of herbicides lead to the birth of environmentally safer new generation of post emergent herbicides, which are effective at very low doses in different crops. Keeping this in view, an attempt was made to find out the effect of application of post emergent herbicides along with intercultivation on weeds, crop productivity and economics of rainy season pearl millet.

Materials and Methods

The experiment was conducted during *kharif*, 2023 at College of Agriculture, Bheemarayanagudi (UAS Raichur) which is situated in North Eastern Dry Zone of Karnataka (Zone-II) at Latitude of 16º15′ North, Longitude of 77º21′ East with an Altitude of 389 meters above mean sea level. The soil sample of the experimental site was medium deep clay soil in texture.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and eight treatments comprising of pre emergent and post emergent herbicides along with cultural practices like hand weeding and intercultivation. The treatments are atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (T_1), atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* ethoxysulfuron 15% WG @ 15 g *a.i.* ha^{-1} as PoE at 20-25 DAS (T_2), atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* penoxsulam 24% SC @ 22.5 g *a.i.* ha^{-1} as PoE at 20-25 DAS (T_3), atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* tembotrione 34.4% SC @ 100 g *a.i.* ha^{-1} as PoE at 20-25 DAS (T_4), atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (T_5), atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (T_6), Weed free check (T_7) and Weedy check (T_8). The pearl millet hybrid used was 30Y93 which is an early maturing (75-85 days) hybrid suitable for rainfed as well as areas with uncertain rainfall patterns with a spacing of 45 cm x 10 cm.

During the course of investigation, in order to know the effect of different herbicides on growth parameters of pearl millet, the observations were recorded at different stages of the crop growth.

Results and Discussion

Growth parameters

A) Plant height

Weed free check recorded significantly higher plant height at 30, 60 DAS and at harvest (36.41, 149.53 and 166.66 cm, respectively) and it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (34.08, 146.07 and 162.31 cm, respectively), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (32.56, 142.87 and 155.21 cm, respectively) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (31.35, 138.13 and 152.05 cm, respectively). Significantly lower plant height was recorded with weedy check at 30, 60 DAS and at harvest (24.61, 116.69 and 116.86 cm, respectively) (Table 1 and Fig. 1).

The higher plant height in weed free check might be attributed due to lesser competition for available growth resources which created due to frequent hand weeding as well as intercultivation. Thus, it resulted in increased internode length due to cell elongation and rapid cell division. Lower plant height was noticed with weedy check due to higher competition among weeds and the crop. Among herbicidal treatments, significantly higher plant height was noticed with the treatments which received intercultivation and application of post emergent herbicides *viz*., 2,4-D Na salt and metsulfuron methyl which might be due to the effect of chemicals on the weeds that reduced the weed density and dry weight which in turn resulted in lesser competition with crops for supply of nutrients, moisture, space and sunlight. These findings were in conformity with the results obtained by Kauri and Singh (2006) [11], Mishra *et al.* (2017) [13] and Tarwariya and Rajput (2019) [21] in pearl millet.

B) Number of tillers per plant

At 30, 60 DAS and at harvest, the number of tillers per plant varied significantly due to different herbicides. Statistically higher number of tillers were found with T_7: Weed free check (2.67, 3.90 and 4.89, respectively) which it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (2.43, 3.62 and 4.65, respectively), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (2.37, 3.55 and 4.46, respectively) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (2.32, 3.49 and 4.27, respectively). Significantly lower number of tillers were observed with T_8: Weedy check at 30, 60 DAS and at harvest (1.77, 2.48 and 3.54, respectively) (Table 1).

The lower number of tillers per plant in weedy check could be attributed due to severe crop-weed competition. A significant reduction in number of tillers might be due to weed competition. The weed free environment provided favourable conditions for uptake of nutrients, moisture and other growth resources which led to better plant growth and resulted in higher number of tillers. These results were in conformity with the findings of Patel *et al*. (2001) [15], Singh *et al*. (2001) [20] and Munde *et al*. (2013) [14] in pearl millet.

C) Total dry matter production

Weed free check recorded significantly higher total dry matter production at 30, 60 DAS and at harvest (11.16, 64.35 and

254.00 g plant^{-1}, respectively). This was followed by T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (10.02, 61.07 and 249.12 g plant^{-1}, respectively), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (9.37, 58.30 and 240.90 g plant^{-1}, respectively) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (8.88, 57.96 and 234.21 g plant^{-1}, respectively). Significantly lower total dry matter production was recorded with weedy check at 30, 60 DAS and at harvest (5.54, 36.99 and 186.52 g plant^{-1}, respectively) (Fig. 2).

Dry matter accumulation indicates the net quantity of photosynthates retained after utilization through respiration which helps in estimating photosynthetic efficiency. Weed management through herbicides had significant influence on dry matter accumulation in different plant parts as well as total dry matter production. Since effective weed control at right stage like critical stage of crop weed competition could minimize the weeds and resulted in higher leaf area and increased photosynthetic activity. Higher dry matter accumulation was found with weed free check due to less competition for the available resources due to absence of weeds. Higher dry matter accumulation in different plant parts would be the indication of higher total dry matter production per plant. Lower dry matter production in weedy check might be due to lower dry matter accumulation in different plant parts like leaves, stem and ear head due to stunted crop growth as there was competition with weeds for available resources. These findings were in conformity with the results obtained by Deshveer and Deshveer (2005) [7], Kauri and Singh (2006) [11] and Ramesh *et al*. (2019) [17] in pearl millet and Dhar *et al*. (2006) [8] in sorghum.

D) Leaf area

All the treatments were found significantly higher than weedy check which recorded lower leaf area of 501.56, 1242.62 and 1104.96 cm^2 plant^{-1}, respectively at all the stages of crop growth *viz*., 30, 60 DAS and at harvest. Weed free check recorded significantly higher leaf area at 30, 60 DAS and at harvest (654.59, 1906.35 and 1409.38 cm^2 plant^{-1}, respectively) and it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (631.89, 1845.13 and 1384.59 cm^2 plant^{-1}, respectively), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (619.56, 1829.67 and 1346.87 cm^2 plant^{-1}, respectively) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (607.56, 1791.58 and 1319.05 cm^2 plant^{-1}, respectively) (Table 2).

Lower leaf area in weedy check might be resulted due to competition for sunlight, space, moisture and nutrients between the crop plants and weeds. It suppressed the growth of the plants and resulted in lesser leaf area per plant. The higher leaf area was observed with weed free check due to absence of weeds which reduced the competition with crop and thus growth was luxurious with increased number of leaves per plant and in turn increased the leaf area per plant. The herbicides *viz*., 2,4-D and metsulfuron methyl also resulted in better weed control and they helped to provide weed free environment and reduced the competition between crop and weeds. The growth and development of the crop was enhanced due to availability of growth resources. Thus, resulted luxurious growth with maximum leaf area which contributed to higher photosynthetic activity. Such similar results were also reported by Kauri and Singh (2006) [11] and Choudhary *et al*. (2022) [5] in pearl millet. The lower leaf area was recorded at the time of harvest because of drying and withering of leaves.

E) Leaf Area Index (LAI)

Significantly higher leaf area index was noticed with weed free check (1.45, 4.29 and 3.13, respectively) at 30, 60 DAS and at harvest and it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (1.40, 4.10 and 3.08, respectively), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (1.38, 4.04 and 2.99, respectively) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (1.35, 3.95 and 2.93, respectively). Weedy check recorded significantly lower leaf area index (1.05, 3.04 and 2.46, respectively) (Table 2).

Leaf area index determines the total assimilating area available to the plant and quantum of source that would ultimately be available for translocation to the sink. The higher leaf area index in weed free check might be due to maximum number of leaves and higher leaf area per plant as a result of increased growth by better utilization of all the available resources because of less competition. Significantly lower leaf area was observed with weedy check plot as the growth was suppressed and resulted in lesser number of leaves and lower leaf area. The treatments in which herbicides *viz*., 2,4-D and metsulfuron methyl were used, was resulted in better weed control efficiency helped the plants to grow more luxuriously and contributed to increase the growth parameters *viz*., number of tillers, number of leaves, leaf area and leaf area index. The decrease in leaf area index at harvest might be due to lesser number of leaves as some of the leaves were dried and withered at harvest stage. These results were similar to that of the findings of Munde *et al.* (2013) [14] and Chinyo *et al*. (2023) [4] in pearl millet.

Table 1: Plant height (cm) and number of tillers per plant of pearl millet as influenced by different herbicides

Treatment	Plant height			Number of tillers per plant		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	31.35	138.13	152.05	2.32	3.49	4.27
T_2	29.23	132.12	145.30	2.12	3.21	4.19
T_3	29.22	127.93	137.77	2.00	3.18	4.11
T_4	28.07	125.33	133.57	1.95	3.15	4.05
T_5	32.56	142.87	155.21	2.37	3.55	4.46
T_6	34.08	146.07	162.31	2.43	3.62	4.65
T_7	36.41	149.53	166.66	2.67	3.90	4.89
T_8	24.61	116.69	116.86	1.77	2.48	3.54
S.Em. ±	2.01	4.26	5.02	0.13	0.14	0.19
C.D. @ 5%	6.11	12.93	15.23	0.39	0.43	0.57

Note:
a.i. = Active ingredient; DAS = Days After Sowing; *fb* = followed by; WP = Wettable Powder; WG = Water Dispersible Granules; SC = Suspension Concentrate; SL = Soluble Liquid; PE = Pre emergence; PoE = Post emergence

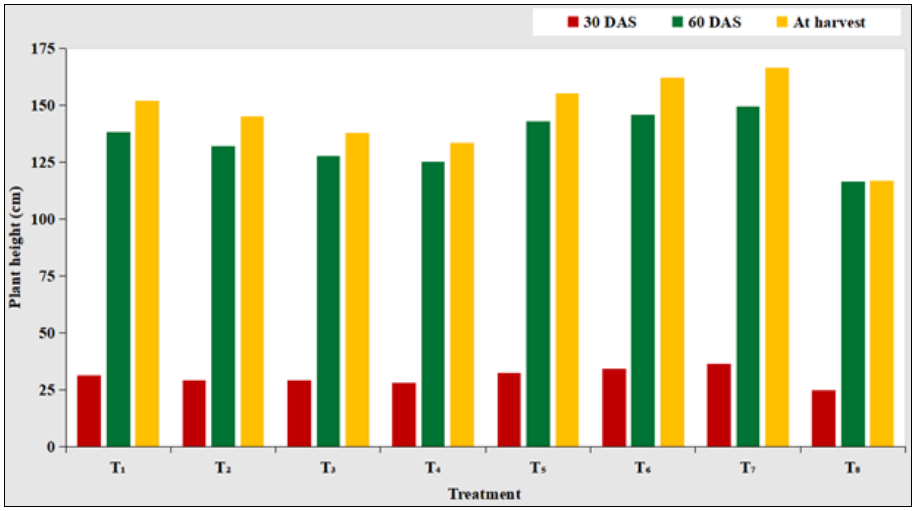

Fig 1: Plant height (cm) at different growth stages of pearl millet as influenced by different herbicides

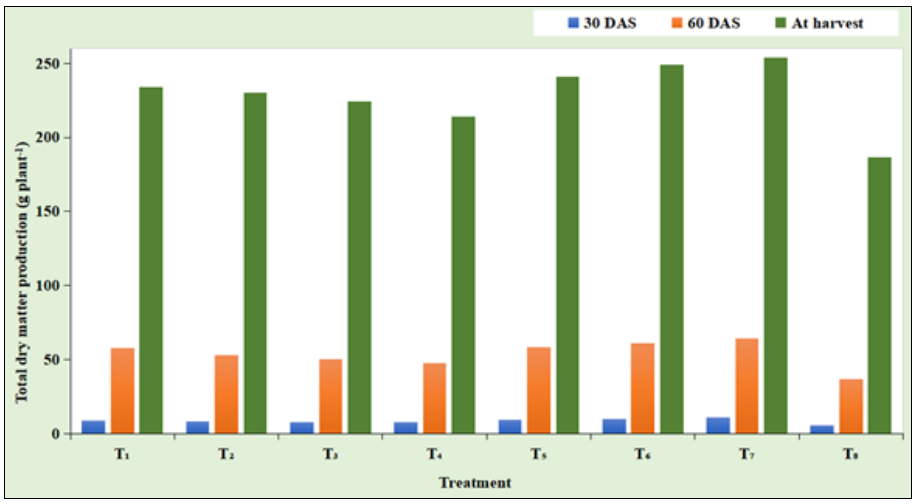

Fig 2: Total dry matter production (g plant^{-1}) at different growth stages of pearl millet as influenced by different herbicides

Table 2: Leaf area (cm^2 plant^{-1}) and leaf area index of pearl millet as influenced by different herbicides

Treatment	Leaf area			Leaf area index		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	607.56	1791.58	1319.05	1.35	3.95	2.93
T_2	601.23	1753.62	1282.64	1.32	3.84	2.85
T_3	596.23	1722.64	1255.37	1.31	3.72	2.79
T_4	581.23	1702.74	1234.56	1.29	3.62	2.74
T_5	619.56	1829.67	1346.87	1.38	4.04	2.99
T_6	631.89	1845.13	1384.59	1.40	4.10	3.08
T_7	654.59	1906.35	1409.38	1.45	4.29	3.13
T_8	501.56	1242.62	1104.96	1.05	3.04	2.46
S.Em. ±	15.81	40.71	38.26	0.04	0.12	0.10
C.D. @ 5%	47.96	123.47	116.06	0.13	0.37	0.31

Note:
a.i. = Active ingredient **DAS** = Days After Sowing ***fb*** = followed by **WP** = Wettable Powder **WG** = Water Dispersible Granules **SC** = Suspension Concentrate **SL** = Soluble Liquid **PE** = Pre emergence **PoE** = Post emergence

Yield parameters and yield

A) Ear head length

Significantly higher ear head length was recorded with T_7: Weed free check (22.95 cm) and it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (22.25 cm), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (21.89 cm) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (21.76 cm) (Table 3 and Fig. 3). It was observed that significantly lower ear head length was recorded with weedy check (16.68 cm) as compared to all other treatments. The significant difference in ear head length among different treatments might be due to difference in photosynthetic activity and chlorophyll content of the leaves. Less crop weed competition might be due to control of weeds at critical stages and resulted in higher length of ear head. These results were similar to the findings of Patel *et al*. (2001) [15] in pearl millet.

B) Grain weight per ear head

The weed free check recorded significantly higher grain weight per ear head (35.65 g) as compared to other treatments and was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (33.73 g), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (32.82 g) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (31.68 g) (Table 3 and Fig. 3). Significantly lower grain weight per ear head was noticed with weedy check (19.28 g). The difference in grain weight per ear head among different treatments might be due to difference in ear head length which might have resulted from increased growth parameters due to better utilization of available resources.

Similar results were obtained by Virkar *et al.* (2007) [22] and Samota *et al*. (2022) [18] in pearl millet.

C) 1000 seed weight

The data related to 1000 seed weight did not differ significantly due to different herbicides and it is presented in Table 4. However, numerically higher 1000 seed weight was obtained with weed free check (12.90 g) and was followed by T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (11.95 g). Lower 1000 seed weight was recorded with weedy check (10.78 g) (Table 3 and Fig. 3). Similar results were also reported by Virkar *et al.* (2007) [22] and Girase *et al.* (2017) [9] in pearl millet.

D) Grain yield

Significantly higher grain yield was recorded with T_7: Weed free check (3075 kg ha^{-1}) and it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (2891 kg ha^{-1}), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (2843 kg ha^{-1}) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (2772 kg ha^{-1}) (Table 3 and Fig. 4). Weedy check was recorded with significantly lower grain yield (1554 kg ha^{-1}) as compared to all other treatments. The variation in grain yield among the treatments might be due to difference in growth and yield parameters. The weed free check recorded significantly higher grain yield which might be due to increase in growth parameters *viz*., plant height, number of leaves, number of tillers and dry matter production and increased yield parameters like ear head length, grain weight per ear head and 1000 seed weight. The decreased grain yield was noticed with weedy check, it could be resulted from decreased growth and yield parameters. Among herbicidal treatments, the treatments which received 2,4-D and metsulfuron methyl as post emergent herbicides decreased the weed density and dry weight which in turn reduced the competition for available resources resulted in increased yield parameters as well as yield. These results were in conformity with the findings of Kauri and Singh (2006) [11], Munde *et al.* (2012) [14] and Choudhary *et al.* (2018) [5] in pearl millet.

Table 3: Yield parameters and yield of pearl millet as influenced by different herbicides

Treatment	Ear head length (cm)	Grain weight per ear head (g)	1000 seed weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
T_1	21.76	31.68	11.68	2772	6567	28.48
T_2	21.10	30.93	11.21	2578	6413	28.36
T_3	20.84	29.85	11.19	2502	6344	28.28
T_4	19.91	26.99	10.96	2386	6162	27.91
T_5	21.89	32.82	11.74	2843	6647	29.33
T_6	22.25	33.73	11.95	2891	6713	29.36
T_7	22.95	35.65	12.90	3075	6984	30.56
T_8	16.68	19.28	10.78	1554	4668	24.58
S.Em. ±	0.53	1.44	0.49	108	148	1.38
C.D. @ 5%	1.60	4.37	NS	328	450	NS

Note:
a.i. = Active ingredient DAS = Days After Sowing *fb* = followed by WP = Wettable Powder
WG = Water Dispersible Granules SC = Suspension Concentrate SL = Soluble Liquid PE = Pre emergence
PoE = Post emergence

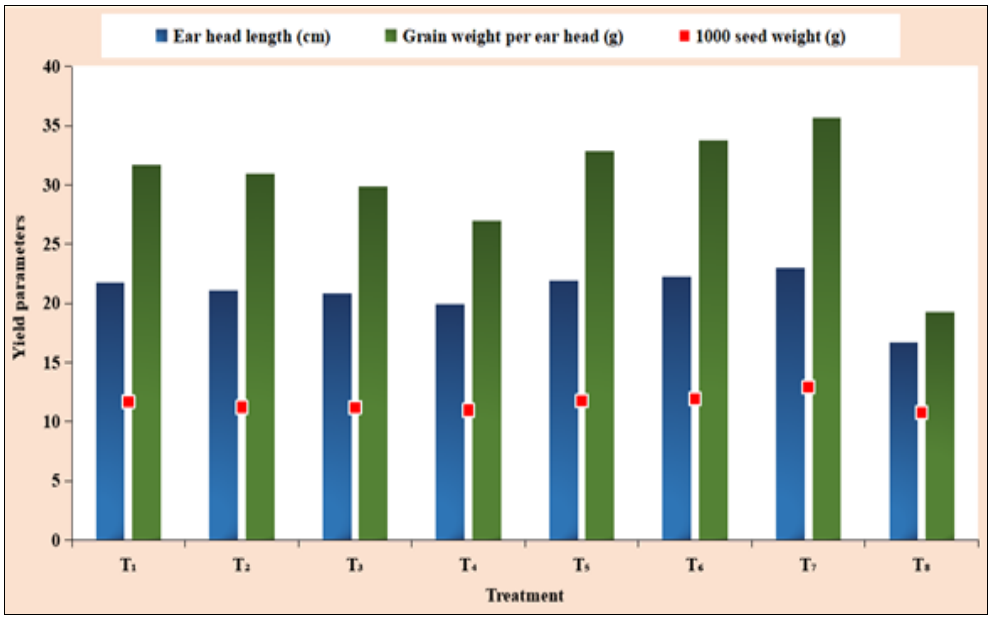

Fig 3: Yield parameters of pearl millet as influenced by different herbicides

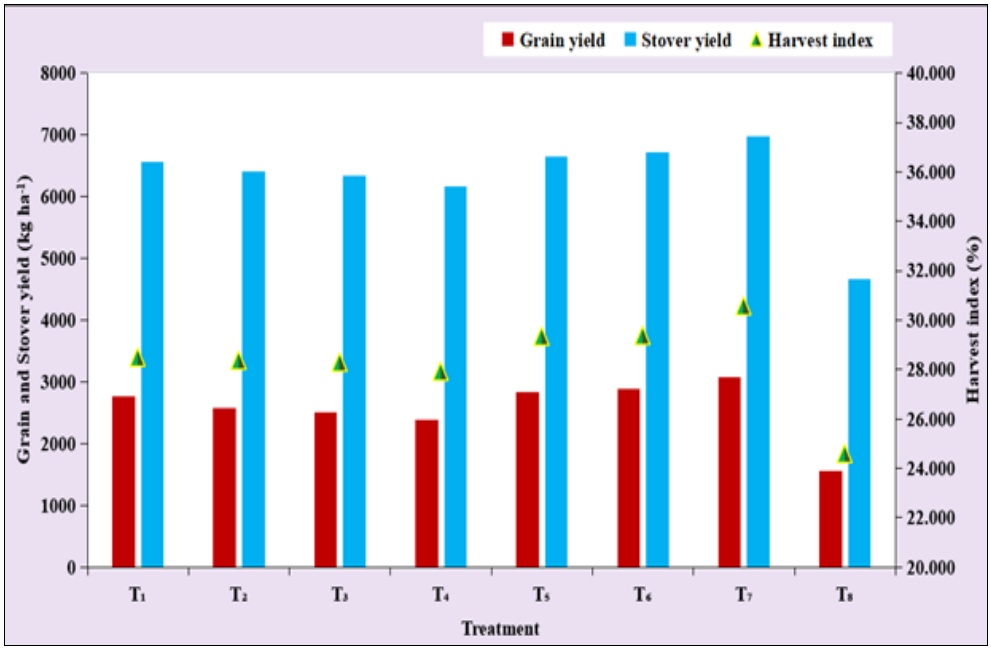

Fig 4: Grain yield, stover yield and harvest index of pearl millet as influenced by different herbicides

E) Stover yield

The weed free check recorded significantly higher stover yield (6984 kg ha^{-1}) as compared to all other treatments and it was found on par with T_6: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (6713 kg ha^{-1}), T_5: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (6647 kg ha^{-1}) and T_1: Atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (6567 kg ha^{-1}). Weedy check recorded significantly lower stover yield (4668 kg ha^{-1}) (Table 3and Fig. 4). The difference in stover yield of pearl millet due to various weed management practices might be due to variations in the growth parameters. The weed free check recorded significantly higher growth parameters *viz*., plant height, number of leaves, number of tillers, total dry matter production and its accumulation in different parts like leaves and stem. It might have influenced the stover yield at the time of harvest. Significantly lower stover yield in weedy check might be resulted from lower growth parameters of pearl millet. Among herbicidal treatments, the treatments which received atrazine as pre-emergent, 2,4-D and metsulfuron methyl as post emergent herbicides recorded higher stover yield, it might be due to lower weed density. The crop plants were grown luxuriantly by utilizing all the available resources like moisture, space, solar radiation and nutrients that in turn increased the growth parameters and resulted in higher stover yield. Apart from these factors, moisture availability at critical stages and better nutrient uptake by the crop might had increased the photosynthetic activity which resulted in higher vegetative growth as well as stover yield. These results were similar to the findings of Kauri and Singh (2006) [11], Girase *et al*. (2017) [9], Kumar *et al*. (2019) [12] and Tarwariya and Rajput (2019) [21] in pearl millet.

F) Harvest Index

The data on harvest index of pearl millet is presented in Table 4. It did not differ significantly among different treatments due to different herbicides. Weed free check recorded numerically higher harvest index (30.56%) and weedy check was recorded with lower harvest index (24.58%) (Table 3 and Fig. 4). Similar findings were given by Kumar *et al*. (2019) [12], Samota *et al*. (2022) [18], Chinyo *et al*. (2023) [4] in pearl millet.

Economics in pearl millet cultivation

Weed free check recorded significantly higher gross returns and net returns (₹ 79,021 and ₹ 43,137 ha^{-1}, respectively). Among herbicidal treatments, atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS recorded significantly maximum gross returns and net returns (₹ 73,449 and ₹ 40,865 ha^{-1}, respectively) and it was followed by atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (₹ 70,134 and ₹ 38,200 ha^{-1}, respectively) and atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (₹ 69,624 and ₹ 37,840 ha^{-1}, respectively). Weedy check was recorded significantly lower gross returns and net returns (₹ 38,853 and ₹ 7,749 ha^{-1}, respectively).

Significantly higher benefit-cost ratio was recorded with atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS (2.25) and it was found on par with weed free check (2.20), atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS (2.20) and atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS (2.19). Significantly lower benefit-cost ratio was obtained with weedy check (1.25) (Fig. 5).

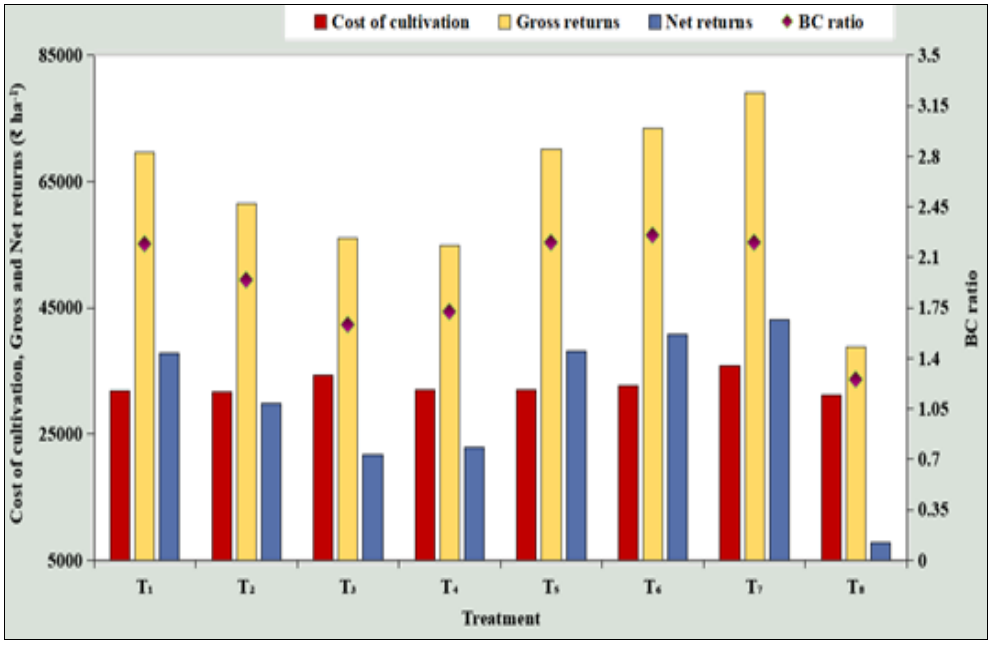

Fig 5: Economics of pearl millet as influenced by different herbicides

Conclusion

Application of atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* intercultivation at 30-40 DAS was found more effective to control weeds and reduced the competition with crop for growth resources and thus resulted in higher growth parameters, yield parameters, yield and economics in pearl millet cultivation. During rainy reason, whenever the cultural practices are not possible due to wet condition of soil, application of atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* 2,4-D 80% WP Na salt @ 500 g ha^{-1} at 20-25 DAS as well as atrazine 50% WP as PE @ 500 g *a.i.* ha^{-1} *fb* metsulfuron methyl 20% WP @ 2 g *a.i.* ha^{-1} as PoE at 20-25 DAS were found beneficial to control weeds more effectively and could be maintained weed free environment during crop growth period of pearl millet. Besides, these treatments would also be more useful in the areas where the labours are scarce and more expensive.

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