Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(3): 207-209
Received: 13-03-2021
Accepted: 16-04-2021

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Protein and starch content in maize (*Zea mays* L.) as influenced by herbicidal weed management

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Abstract
A field experiment was conducted during *kharif* 2018-19 College of Agriculture, Latur to find out the effective herbicides for control of weeds in maize (*Zea mays* L.). The experiment comprise of 10 treatment combinations. Application of pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE) was significantly superior in reducing weed density and dry weight of weeds and hence improved the protein and starch content. Weed free check, pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE), pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i. ha^{-1} (30 DAS) and atrazine 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE) registered 12.00, 11.63, 11.03 and 10.93 % protein and 63.70, 62.17, 60.83 and 60.50 % starch respectively as against the protein and starch content of weedy check 7.13 and 58.87 respectively. (PoE-Post Emergence, PE-Pre Emergence).

Keywords: Herbicide, maize, protein, starch, weed management, yield

Introduction
Maize (*Zea mays* L.) or Indian corn is an essential crop which highly contributes to the world agriculture and more importantly to the world's food basket. In India, maize covers 9.28 m ha area with the productivity of 2.82 MT ha^{-1} during 2018-19 (Ministry of Agriculture, India). Maize occupies importance as a human food (25%), poultry supplement (49%), animal supplement (12%), and industrial products such as starch (12%). Maize also contains maximum genetic yield potential, therefore maize is known as "Queen of cereals" (India Maize Summit, 2018). Weeds usually reduces crop yield up to 31.5% (22.7% in *rabi* and in *kharif* 36.5%). But as farmers adopt some kind of weeding on their crop field, a conservative estimate of 10% loss in crop yields may be taken as more realistic, hand weeding is most effective if done in time, though it is costly and time consuming. Apart from this, labourers are not available for weeding owing to other agricultural operation going on simultaneously. Additionally, manual method of weed control cannot be put into practice until weeds have achieved certain heights. In *kharif* maize, problem of severe weed infestation level combined with various species of weeds. Almost every type of weeds namely grassy, broad leaved and sedges infest the maize fields. As they compete for moisture, nutrients, space, light, shelter for many diseases and pest ultimately disturbs the growth of the plants, reduce the yield and also deteriorates the quality of crop, hence reduce the protein and starch content. Sharma *et al*., (2000) [6] reported that the reduction (33-50%) in grain yield due to weed infestation. The higher loss in crop yield due to weed competition and it is evaluated that during the 1st 3-6 weeks (Shad *et al*., 1997) [5]. Therefore, there is a need for some alternate herbicides or sequential application of herbicide, which gives broad spectrum and season long control of weeds during the critical period in *kharif* maize, without affecting the crop growth and crop yield. In a view of paucity of information on effect of pre and post-emergence herbicide application on quality of maize, an attempt has been made to test pre-emergence and post-emergence herbicides.

Materials and Methods
A field experiment was conducted during *kharif* 2018-19 College of Agriculture, Latur to find out the effective herbicides for control of weeds in maize (*Zea mays* L.). The experiment comprises of ten treatment combinations and three replications under randomized block design with the net plot area (16.56 m^2).The soil of experimental site was medium and black in color with good drainage and low in available nitrogen (125.3 kg ha^{-1}), medium in available phosphorous (18.20 kg ha^{-1}) and very high in available potassium (498.58 kg ha^{-1}). The soil was moderately alkaline in reaction having pH (7.7). Maize *'Mahabeej-Uday'* was sown on 02 August 2019 at 60 cm row to row and 30 cm plant to plant spacing using 15 kg ha^{-1} seed rate and was harvested on 01 December 2019. Recommended dose of fertilizers (150 kg N + 75 kg P + 75 kg, kg ha^{-1}) was applied.

The doses of herbicides were computed as per treatments. The stock solution of desired concentration was prepared as per treatment for each plot and the herbicides were applied with knap sack sprayer. The pre-emergence herbicides were applied 24 hours after sowing and in case of post-emergence herbicides they were applied as per the treatments. Treatments were as follows, T_1- Weedy check, T_2- Weed free check, T_3- Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i. ha^{-1} (PoE), T_4- Atrazine 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE), T_5- Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* halosulfuron-methyl 90 g a.i. ha^{-1} (PoE), T_6- Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i. ha^{-1} (30 DAS), T_7- Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE), T_8- Halosulfuron-methyl 90 g a.i. ha^{-1} (PoE), T_9- Tembotrione 120 g a.i. ha^{-1} (PoE), T_{10}- 2,4-D amine 1000 g a.i. ha^{-1} (PoE) (*fb- Followed by*). The observations on weed population was recorded at 30, 45 and 60 DAS and data was analyzed using square root transformation (X + 0.5). The yield recorded at net plot basis converted to hectare and expressed in kg ha^{-1}. The data was statistically analyzed by adopting Fishers methods of analysis of variance as outlined by Gomez and Gomez (1984) [3]. The protein content (%) was estimated by multiplying the nitrogen percentage by 6.25. Nitrogen percentage was estimated by Microkjeldahal method. Starch was estimated by iodine test using glucose as standard by using Sullivian's method.

Results and Discussion

Weed dynamics

The experimental field was infested with *Commelina benghalensis L., Acalypha indica L., Amaranthus viridis, Euphorbia spp., Parthenium hysterophorun, Corchorus fascicularis L., Abutilon hirtum (Lam.), Boerhavia coccinea, Phyllanthus niruri, Argemone Mexicana L., Euphorbia geniculata Orteg., Achyranthus aspera L., Cardiospermum helicacabum L., Xanthium strumarium L., Celosia argentea L.* under broad leaved weeds followed by grasses *Sorghum halepense L., Cynodon dactylon L. Pers., Eriochloa spp. and* sedges *Cyperus rotundus L.*

Table 1: Effect of weed control treatments on density and dry weight of weeds, weed control efficiency (%), weed index (%), herbicide efficiency index (%)

Treatment	Weed density (1m^2)			Weed dry weight (g/net plot*)	Weed control efficiency (%)	Weed index (%)	Herbicide efficiency index (%)
	30 DAS	45 DAS	60 DAS				
Weedy check	6.19** (37.83)	6.57 (42.67)	6.81 (45.94)	96.17 (9250.06)	0.00	131.42	0.00
Weed free check	2.81 (7.44)	1.87 (3.00)	1.52 (1.84)	23.51 (552.63)	94.03	0.00	22.00
Atrazine 1000 g a.i./ha (PE) *fb* Halosulfuron-methyl 90 g a.i./ha (PoE)	2.67 (6.66)	3.38 (10.98)	3.06 (8.88)	40.02 (1601.36)	82.69	50.91	3.08
Atrazine 1000 g a.i./ha (PE) *fb* 2,4-D amine 1000 g a.i./ha (PoE)	2.67 (6.66)	2.68 (6.70)	1.96 (3.35)	33.97 (1153.46)	87.53	21.12	7.30
Pendimethalin 1000 g a.i./ha (PE) *fb* halosulfuron-methyl 90 g a.i./ha (PoE)	3.05 (8.83)	3.1 (9.11)	2.75 (7.11)	35.37 (1250.96)	86.48	39.72	4.85
Pendimethalin 1000 g a.i./ha (PE) *fb* tembotrione 120 g a.i./ha (30 DAS)	2.49 (5.72)	2.05 (3.71)	1.75 (2.57)	30.95 (957.73)	89.65	14.15	9.92
Pendimethalin 1000 g a.i./ha (PE) *fb* 2,4-D amine 1000 g a.i./ha (PoE)	2.35 (5.04)	1.91 (3.16)	1.74 (2.56)	27.32 (745.9)	91.94	3.86	15.23
Halosulfuron-methyl 90 g a.i./ha (PoE)	5.24 (27.00)	3.73 (13.44)	3.93 (15.00)	61.82 (3821.43)	58.69	79.85	0.69
Tembotrione 120 g a.i./ha (PoE)	5.29 (27.58)	2.96 (8.27)	2.90 (7.93)	60.5 (3660.9)	60.42	56.42	1.21
2,4-D amine 1000 g a.i./ha (PoE)	5.22 (26.83)	2.91 (8.00)	2.30 (4.79)	34.07 (1160.36)	87.46	30.37	6.18
SE ±	0.72	0.48	0.58	98.13	-	-	-
CD 5%	2.14	1.43	1.74	291.52	-	-	-

*16.56 m^2, ** data in parenthesis (original value) was subjected to $\sqrt{X + 0.5}$ transformation.

At 30 DAS, significant reduction in total weed density was recorded under herbicidal treatment Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE), which was at par with Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE), Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) and Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) but significantly superior over other herbicidal treatments. At 45 DAS, minimum total weed density was observed in Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) which was at par with Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) and found significantly superior over other herbicidal treatments. At 60 DAS, significant reduction in total weed density was recorded under herbicidal treatment Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE), which was at par with Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) and Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) and found significantly superior over rest of the herbicidal treatments. Although, Weed free check showed lowest total weed density. Whereas highest total weed density was observed in Weedy check. Total dry weight of weeds was significantly reduced under Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) followed by Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) as compared to other herbicidal treatments.

It might be due to two fold action of this combination and sequential application that affected both grasses as well as broad leaf weeds. The greater effectiveness of Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) has also been reported by Biswas *et al*. (2018) [2] and Barua S. (2019) [1], who observed least total weeds dry weight under these combination (Table 1). Maximum weed index was observed in Weedy check, followed by Halosulfuron-methyl 90 g a.i./ha (PoE), Tembotrione 120 g a.i./ha (PoE) and Atrazine 1000 g a.i./ha (PE) *fb* Halosulfuron-methyl 90 g a.i./ha (PoE). Whereas, minimum weed index was found in Weed free check followed by Pendimethalin 1000 g a.i./ha (PE) *fb* 2,4-D amine 1000 g a.i./ha (PoE), Pendimethalin 1000 g a.i./ha (PE) *fb* tembotrione 120 g a.i./ha (30 DAS), Atrazine 1000 g a.i./ha (PE) *fb* 2,4-D amine 1000 g a.i./ha (PoE). Higher weed control efficiency and herbicide efficiency index among herbicidal treatments was noticed in Pendimethalin 1000 g a.i./ha (PE) *fb* 2,4-D amine 1000 g a.i./ha (PoE) followed by Pendimethalin 1000 g a.i./ha (PE) *fb* tembotrione 120 g a.i./ha (30 DAS).

Effect on protein, starch content and yield

Data regarding protein and starch content showed that the differences in protein and starch content were statistically non-significant (Table 2). Quality of protein and starch percent were recorded highest under treatment, (Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE)) recorded percent (11.63% and 62.17% respectively), followed by (Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i. ha^{-1} (30 DAS)), (11.03% and 60.83% respectively). Although (Weed free check) showed the maximum protein and starch content (12.00% and 63.70% respectively). Similar results were found by Khan *et al*. (2014) [4]. Protein and starch content in maize is highly influenced by the weed density present in the plots of experimental treatments. Treatments which had low density of weeds resulted in high quantity of protein and starch and the treatments which had high weed density resulted in the low quantity of protein and starch in maize. Among all the treatments, statistically higher kernel yield (kg ha^{-1}) was observed in Weed free check i.e. 6335.23 kg ha^{-1}, which was at par with Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) having kernel yield 6099.73 kg ha^{-1} and Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) having kernel yield 5549 kg ha^{-1}, but significantly superior over other herbicidal treatments. Of all the treatments Weedy check showed the lowest kernel yield (kg ha^{-1}) i.e. 2737 kg ha^{-1} as compared to any other treatments.

Table 2: Effect of weed control treatments on yield (kg ha^{-1}), Protein and Starch content

Treatment	Kernel Yield kg ha^{-1}	Protein (%)	Starch (%)
Weedy check	2737	7.13	58.87
Weed free check	6335	12.00	63.70
Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	4198	8.20	59.33
Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE)	5230	10.93	60.50
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	4534	8.90	60.33
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS)	5549	11.03	60.83
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE)	6099	11.63	62.17
Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	3522	7.00	59.53
Tembotrione 120 g a.i.ha^{-1} (PoE)	4050	7.73	59.23
2,4-D amine 1000 g a.i.ha^{-1} (PoE)	4859	9.97	61.67
SE ±	288	1.28	1.01
CD 5%	856	NS	NS

Conclusion

Based on the result it can be inferred that application of Pendimethalin 1000 gm a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 gm a.i. ha^{-1} (PoE) is proved to be most effective in controlling weeds, gave higher yield, although hand weeding is the best. Quality of protein and starch percent were recorded highest under treatment, Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE) recorded percent (11.63% and 62.17% respectively), followed by Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i. ha^{-1} (30 DAS), (11.03% and 60.83% respectively). Although Weed free check showed the maximum protein and starch content (12.00% and 63.70% respectively).

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