



Research Article

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Nodulation and Yield Response of Cowpea [*Vigna unguiculata* (L) Walp.] to Integrated Use of Planting Pattern and Herbicide Mixtures in Wollo, Northern Ethiopia



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Abstract

To assess the integrated effect of planting pattern and low dose herbicide mixtures on nodulation, yield attributes and yields of cowpea and to determine the economic feasibility of different weed management practices in cowpea, a field experiment was conducted at Haik and Mersa in Northern Ethiopia during the 2014 main cropping season. Fourteen treatments were applied and arranged in factorial arrangement in a randomized complete block design with three replications. The results revealed that higher weed dry biomass and lower plant height were obtained in weedy check plots. The plants at Haik had significantly 44.2 % higher effective nodules than at Mersa. Higher number of pod plant⁻¹, number of seeds pod⁻¹, and hundred seed weight were obtained from the interaction of s-metolachlor at 1.0kg h⁻¹ + hand weeding 35 DAE along with 60cmx10cm.

The weed management practices revealed that hand weeding and hoeing 3 WAE gave the highest (59.2mg plant⁻¹) nodule dry weight followed by pendimethalin at 1.0kg h⁻¹ supplemented with one hand weeding and hoeing at 5 WAE. The maximum grain yield (3092kg h⁻¹) was recorded from Mersa than Haik (2714kg h⁻¹). The highest gross benefit was obtained from s-metolachlor at 1.0kg h⁻¹+ hand weeding and hoeing 35dae (53460 ETB h⁻¹) followed by pendimethalin at 1.0kg h⁻¹+ hand weeding and hoeing 35dae (46737 ETB h⁻¹). Therefore, managing the weeds with the application of 1.0kg h⁻¹ of Pendimethalin + hand weeding and hoeing 35 DAE proved to be the most profitable practice. However, in a situation of unavailability of herbicide on time, hand weeding and hoeing three WAE seemed to be an alternate weed management practice.

Keywords: Broadleaved and grass weeds; Cowpea, Grain yield; Herbicide mixtures; Nodulation; weed

Introduction

Cowpea is a member of the Phaseoleae tribe of the Fabaceae family. Members of the Phaseoleae include many of the economically important warm season grains and oilseed legumes, such as soybean (*Glycine max* (L.) Merrill), common bean and mung bean. It is one of the most important food and forage legumes in the semi-arid tropics that include parts of Africa, Asia, Central and South America, Southern Europe and Southern United States [1]. It is truly a multifunctional crop, providing food for people and livestock, and serving as a valuable and dependable income generating commodity for farmers and grain traders [2].

Cowpea yield loss due to weed interference was described up to 96 %, this indicates the importance of weed management in this

crop [3,4] stated that the reduction in yield of cowpea depends on the weed species, weed density and weed dry biomass. Also, [5] described that cowpea is sensitive to competition of weeds; 2 to 100 plants m⁻² density of *Solanum nigrum* plant, decreased cowpea yield between 13 and 77%. [6] also reported up to 40% yield loss in cowpea due to the competition of *S. nigrum*. They also found that for every 100kg dry weight of weeds, cowpea yield was reduced by about 208 kg ha⁻¹.

The use of herbicides is often considered an effective alternative to hand weeding. This alternative is often applicable to large hectares of farm land where hand weeding may not be feasible due to labour and other logistic constraints. The increasing scarcity and high cost of labour for manual weeding

necessary to achieve adequate yields of cowpea in Ethiopia have led to growing interest in herbicides. Nonetheless, cowpea is believed to be more sensitive to herbicides than other leguminous species [7]. Therefore, herbicide combination is applied to broaden the spectrum of weeds controlled and sometimes combinations can give spectacularly good control at doses considerably below those normally applied in single application. The use of herbicide combinations is not new, but it has not received the attention and input that is necessary to fully understand and implement the practice.

The present study therefore is aimed at to assess the integrated effect of planting pattern and low dose herbicide mixtures on nodulation, yield attributes and yields of cowpea and to determine the economic feasibility of different weed management practices in cowpea.

Materials and Methods

Description of the study area

The experiment was conducted at Haik and Mersa in Northern Ethiopia during the 2014 main cropping season. The total rainfall received during the crop season was 1083.7 and 991.6mm at Mersa and Haik with mean maximum and minimum temperatures of 27.7 and 14.9 °C and 27.1 and 16.9 °C, respectively.

Treatments and experimental design

There were 16 treatments comprising the combinations of two planting patterns (60cmx10cm and 45cmx15cm) and eight weed management practices (s-metolachlor 2.0kg ha⁻¹, s-metolachlor at 1.0kg ha⁻¹ + hand weeding and hoeing 35 days after crop emergence (dae), pendimethalin at 1.0kg ha⁻¹ + hand weeding and hoeing 35 dae, s-metolachlor at 1.0kg ha⁻¹+pendimethalin at 1.0kg ha⁻¹, s-metolachlor at 1.0kg ha⁻¹+pendimethalin at 0.75kg ha⁻¹, s-metolachlor at 0.75kg ha⁻¹+pendimethalin at 1.0kg ha⁻¹, hand weeding and hoeing 21 dae and weedy check. The treatments were arranged in factorial arrangement in a randomized complete block design with three replications. The gross plot size was 3.6mx2.4m. The cowpea variety Asrat (IT 92KD-279-3) which is bush and trailing type I was planted on July 22 and 23, 2014 at Haik and Mersa, respectively. Thus the net plot was 1.8mx1.8m. The crop was harvested on October 28 and November 7, 2014 at Mersa and Haik, respectively.

Data collection and analysis

Data on weed flora present in the experimental fields were recorded during the experimental period. The weed count was taken at harvest. Data on weed dry weight or biomass, the weeds falling within the quadrat were cut near the soil surface immediately after taking observation on weed count and placed into paper bags separately treatment wise. The dry weight was expressed in g m⁻². Plant height (cm) was taken with a meter from 10 randomly selected and pre tagged plants in each net plot

area from the base to the apex of the main stem at physiological maturity. Bulk of roots of 5 randomly taken plants from the net area in each treatment was carefully exposed at 50% flowering and uprooted for nodulation study. Roots were carefully washed using tap water on a sieve and nodules were separated and counted. Effectiveness of the nodules was checked by cutting the nodule for color judgment and was considered pink as effective and cream white as ineffective. The nodules were dried in an oven at 65 °C to a constant weight to determine nodule dry weight per plant.

However, the plants used for these observations were considered for yield adjustment at harvest. Number of pods plant⁻¹ was taken from the total pods of the tagged plants at harvest. The total number of seeds from the above pods was taken and counted to average the number of seeds pod⁻¹. Out of seeds from the above, 100 seeds were counted and their weight was recorded at 10.5% moisture content for hundred seed weight (g). Harvest index (%) was determined by harvesting ten plants in each plot at physiological maturity and their dried aboveground biomass (grain and straw) was recorded. The grain yield (kg ha⁻¹) was measured after threshing the sun dried plants harvested from each net plot and the yield was adjusted at 10.5% seed moisture content by using the formula: Adjusted grain yield (kg ha⁻¹) = Actual yield x 100-M /100-D Where M is the measured moisture content, D is the designated moisture content

Data on weed dry biomass; nodules, yield attributes and yield were analyzed using Gen Stat 15.0 computer software [8]. Fisher's protected Least Significant Difference (LSD) test was used to separate differences among treatment means (P<0.05) [9]. As the F-test of the error variances of the two sites was homogeneous, combined analysis of data was used.

Partial budget analysis

The concepts used in the partial budget analysis were the mean grain yield of each treatment in both locations, the field price of cowpea (sale price (Birr 15kg⁻¹) minus the costs of harvesting, threshing and winnowing (Birr 165/100kg) bagging (Birr 4.0 per 100 kg⁻¹) and transportation (Birr 5 per 100 kg⁻¹), the gross field benefit (GFB) ha⁻¹ (the product of field price and the mean yield for each treatment), the field price of s-metolachlor 417Birr kg⁻¹, cost of pendimethalin 620 Birr kg⁻¹ (the herbicide cost plus the cost of transportation from the point of sale to the farm), the total costs that varied (TCV) included the sum of field cost of herbicide and its application (Spraying Birr 99ha⁻¹). The net benefit (NB) was calculated as the difference between the GFB and the TCV. All costs and benefits were calculated on ha basis in Ethiopian Birr. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. There were optimum plant population density, timely labor availability and better management (e.g. weed control, better security) under experimental conditions [10,11].

Results and Discussion

Effect of weed management practices on weeds

Table 1: Weed community recorded in cowpea field at the experimental sites in 2014 cropping season.

| Weed Species | Family | Life Form (Category) |
|---|---------------|----------------------|
| <i>Amaranthus spinosus</i> L. | Amaranthaceae | Annual (broadleaved) |
| <i>Amaranthus hybridus</i> L. | Amaranthaceae | Annual (broadleaved) |
| <i>Bidens pilosa</i> L. | Asteraceae | Annual (broadleaved) |
| <i>Commelina benghalensis</i> L. | Commelinaceae | Annual (broadleaved) |
| <i>Cyperus esculentus</i> L. | Cyperaceae | Annual (sedge) |
| <i>C. rotundus</i> L. | Cyperaceae | Perennial (sedge) |
| <i>Datura stramonium</i> L. | Solanaceae | Annual (broadleaved) |
| <i>Galinsoga parviflora</i> Cav. | Asteraceae | Annual (broadleaved) |
| <i>Orobanche crenata</i> Forsk. | Orobanchaceae | Annual (broadleaved) |
| <i>Oxalis latifolia</i> Kunth. | Oxalidaceae | Annual (broadleaved) |
| <i>Seteria verticillata</i> (L.) Beauv. | Poaceae | Annual (grass) |
| <i>Solanum nigrum</i> L. | Solanaceae | Annual (broadleaved) |
| <i>Tagetes minuta</i> L. | Asteraceae | Annual (broadleaved) |
| <i>Xanthium strumarium</i> L. | Asteraceae | Annual (broadleaved) |

Weed community: The major weeds in the experimental fields were the broadleaved (Table 1). The fourteen weed species found infesting the experimental fields belonged to eight families. The parasitic weed *Orobanche* (*Orobanche crenata*) was found at Haik in plots infested with *Xanthium strumarium* only. The other weed species were found at both locations.

Weed dry biomass: Statistical analysis of the data indicated that the aboveground weed dry biomass at harvest was significantly influenced by location, weed management practices and the interactions of location with weed management practices, and planting pattern with weed management practices. The minimum weed dry weight (30.4g m^{-2}) recorded at Mersa from s-metolachlor at 1.0kg ha^{-1} +hand weeding and hoeing 35dae was statistically at par with the application of s-metolachlor at 2.0kg ha^{-1} , pendimethalin at 1.0kg ha^{-1} + hand weeding and hoeing 35dae, s-metolachlor at 1.0kg ha^{-1} +pendimethalin at 1.0kg ha^{-1} and hand weeding and hoeing at 21dae at Mersa and s-metolachlor at 1.0kg ha^{-1} + hand weeding and hoeing 35dae at Haik. According to [12] pre emergence application of Stomp-330 E at 1.25 and 1.50kg ha^{-1} +hand weeding were equally and much more effective in reducing dry weight of weeds [13]. Also concluded that dry weight of weeds was significantly reduced in herbicide treated plots of common bean. Similar outcome also reported by [14] who stated that preemergence herbicides reduced the weed density and dry weight significantly as compared to weedy check in common bean (Table 2 & 3).

Table 2: Interaction effect of location by weed management practices and planting pattern with weed management practices on total weed dry biomass of cowpea at harvest during 2014 main cropping season. Means in the same column followed by the same letters are not significantly different at 5% level of significance LSD= least significant difference; CV= coefficient of variation dae=days after crop emergence.

| Factors | Location (L) | | Planting Pattern (P) | |
|---|--------------|----------|----------------------|----------|
| | Haik Mersa | | S1 S2 | |
| S-metolachlor at 2.0kg ha^{-1} | 100.6d-g | 72.1e-h | 88.0def | 84.7def |
| S-metolachlor at 1.0kg ha^{-1} +hand weeding and hoeing 35dae | 50.4gh | 30.4h | 29.8g | 50.9fg |
| Pendimethalin at 1.0kg ha^{-1} +hand weeding and hoeing 35dae | 100.7d-g | 53.8fgh | 81.8d-g | 72.7efg |
| S-metolachlor at 1.0kg ha^{-1} +pendimethalin at 1.0kg ha^{-1} | 115.2cde | 77.2e-h | 62.0fg | 130.4bcd |
| S-metolachlor at 1.0kg ha^{-1} +pendimethalin at 0.75kg ha^{-1} | 162.9bc | 107.8def | 152.6bc | 118.0cde |
| S-metolachlor at 0.75kg ha^{-1} +pendimethalin at 1.0kg ha^{-1} | 202.0b | 110.0cde | 183.9b | 128.1cd |
| Hand weeding and hoeing 21dae | 109.3cde | 73.6e-h | 91.8def | 91.0def |
| Weedy check | 472.4a | 136.9cd | 281.8a | 327.5a |
| LSD(5%) L x W/ P x W | 54.31 | | | |
| CV (%) | 38.1 | | | |

Table 3: Interaction effect of location and weeding frequency on plant height (cm) of cowpea in 2014 cropping season.

| | Location (L) | |
|--|--------------|--------|
| | Haik | Mersa |
| Weeding frequency (W) | | |
| One hand weeding and hoeing at 2 WAE | 70.1b | 57.8cd |
| One hand weeding and hoeing at 3 WAE | 73.4b | 56.8cd |
| One hand weeding and hoeing at 4 WAE | 73.6b | 54.1d |
| Two hand weeding and hoeing at 2 and 5 WAE | 69.0b | 57.3cd |
| Weed free check | 70.7b | 59.0cd |
| Weedy check | 85.7a | 62.7c |
| LSD (5%) L x W | 6.1 | |
| CV (%) | 9.9 | |

Means within columns and rows having the same letter(s) are not significantly different at

5% level of significance; WAE: Weeks after Crop Emergence; LSD: Least Significant Difference;

CV: coefficient of variation

Effect of weed management practices on growth parameters

Table 4: Main effect of location and weed management practices on total number of nodules, effective number of nodules and nodule dry weight (mg plant⁻¹) of cowpea in 2014 cropping season.

| Factors | Total Number of Nodules | Effective Number of Nodules | Nodule Dry Biomass (mg Plant ⁻¹) |
|--|-------------------------|-----------------------------|--|
| Location | | | |
| Haik | 84 | 39.8 ^a | 36.1 ^b |
| Mersa | 80 | 27.6 ^b | 44.5 ^a |
| LSD (5%) | NS | 4.4 | 1.4 |
| S-metolachlor at 2.0kg ha ⁻¹ | 70.9d | 22.2 ^c | 27.3 ^c |
| S-metolachlor at 1.0kg ha ⁻¹ +hand weeding and hoeing 5 WAE | 92.7bc | 40.0 ^b | 53.0 ^b |
| Pendimethalin at 1.0kg ha ⁻¹ +hand weeding and hoeing 5 WAE | 85.3c | 47.6 ^{ab} | 53.6 ^{ab} |
| S-metolachlor at 1.0kg ha ⁻¹ + pendimethalin at 1.0kg ha ⁻¹ | 67.5d | 22.2 ^c | 24.8 ^c |
| S-metolachlor at 1.0kg ha ⁻¹ + pendimethalin at 0.75kg ha ⁻¹ | 72.2d | 24.3 ^c | 26.8 ^c |
| S-metolachlor at 0.75kg ha ⁻¹ + pendimethalin at 1.0kg ha ⁻¹ | 64.2d | 17.9 ^c | 24.3 ^c |
| Hand weeding and hoeing 3 WAE | 104.0a | 49.9 ^a | 59.2 ^a |
| Weedy check | 98.9ab | 45.4 ^{ab} | 53.1 ^b |
| LSD (5%) | 11 | 8.8 | 5.6 |
| CV (%) | 16.5 | 32.2 | 17 |

CV: Coefficient of Variation; LSD: Least Significant Difference; DAE: Days After Crop Emergence; Means In Column of Same Parameter Followed By The Same Letter(S) Are Not Significantly Different At 5% Level of Significance; NS: Not Significant.

Plant height: The data revealed significant reduction in plant height under respective weeding frequencies at Mersa compared to Haik. Higher plant height at Haik than at Mersa might be attributed to differences in weather conditions especially temperature, whereby Haik had probably more conducive environmental conditions for growth and development of weeds. Under such conditions, plants might grow taller to compete for light. The observed increase in plant height in presence of severe weed interference could therefore be due to intense competition between weeds and crop plants and their desire to reach for the essentials of life, light energy in this case. The plants at Haik attained significantly higher height in weedy check plots than all the other treatments. The lowest plant height (54.1cm) was obtained with one hand weeding and hoeing at 4 WAE at Mersa which was significantly lower than all the treatments at Haik and weedy check at Mersa (Table 4).

This result was in line with the findings of [15] who observed that cowpea height is dependent on weed control treatments in Nigeria. Higher plant height obtained in weedy check plots at both locations might be due to the competition offered by the weeds throughout the season especially to light. Thus, such competition might have resulted in enhanced plant height. There was no significant effect of planting pattern on plant height which was in accord with that of [16] who also found no significant effect of plant density on plant height of cowpea. In contrast, [17] found the tallest plants from closer row spacing in cowpea.

Similar results were reported by [18], who indicated that the denser plant population increased the plant height due to competition among plants in faba bean. In field pea [19] indicated that denser plant population increased plant height due to competition among plants. This might be due to close row spacing, the space for plant spreading was less and hence plant height increased significantly. On the other hand, in chickpea [20] also observed reduction in plant height under closer row spacing. The variable results with denser population among the crops may be due to difference in canopy structure and /or the growth habit.

Number and dry weight of nodules: The main effect of weed management practices showed that hand weeding and hoeing 3 WAE gave the highest (104.0 plant⁻¹) total number of nodules that did not differ significantly from the weedy check treatment. It was also observed that the total number of nodules decreased significantly with the application of herbicide mixtures and s-metolachlor at 2.0kg ha⁻¹ (Table 4). This result agrees with other researchers that herbicides can influence the success of the legume-Rhizobium symbiosis either by affecting the plant, the rhizobia or both [21]. Although many researchers have concluded that the impact of herbicide application on the

symbiotic partnership is due largely, or exclusively, to direct effects of the herbicide on plant growth and consequent photosynthate allocation to the nodules [22,23], others have argued that herbicides may inhibit the survival and/or functioning of the rhizobial partner [24,25].

The observed difference in effective number of nodules plant⁻¹ appeared to be highly significant due to main effect of location and weed management practices. The plants at Haik had significantly 44.2% higher effective nodules than at Mersa. The main effect of weed management practices showed the highest (49.9 plant⁻¹) effective number of nodules for hand weeding and hoeing 21 days after crop emergence, but was at par with the application of pendimethalin at 1.0kg ha⁻¹ + hand weeding and hoeing 5 WAE. This might have resulted in less competition with weeds for resources resulting in higher number of effective nodules plant⁻¹ (Table 5 & 6).

Table 5: Interaction effect of location by weed management practices on number of pods plant⁻¹ of cowpea during 2014 main cropping season.

| | Location (L) | |
|--|---------------------|---------------------|
| Weed management practices (W) | Haik | Mersa |
| S-metolachlor at 2.0kg ha ⁻¹ | 17.8 ^{ef} | 28.3 ^{ab} |
| S-metolachlor at 1.0kg ha ⁻¹ + hand weeding and hoeing 35dae | 22.9 ^{cd} | 31.8 ^a |
| Pendimethalin at 1.0kg ha ⁻¹ + hand weeding and hoeing 35dae | 21.3 ^{de} | 30.3 ^{ab} |
| S-metolachlor at 1.0kg ha ⁻¹ + pendimethalin at 1.0kg ha ⁻¹ | 16.7 ^{efg} | 27.9 ^{ab} |
| S-metolachlor at 1.0kg ha ⁻¹ + pendimethalin at 0.75kg ha ⁻¹ | 15.7 ^{fg} | 26.1 ^{bcd} |
| S-metolachlor at 0.75kg ha ⁻¹ + pendimethalin at 1.0kg ha ⁻¹ | 16.2 ^{fg} | 27.3 ^{abc} |
| Hand weeding and hoeing 21dae | 16.8 ^{efg} | 26.0 ^{bcd} |
| Weedy check | 12.5 ^e | 12.2 ^g |
| LSD(5%) L x W | 4.9 | |
| CV(%) | 19.4 | |

Means in the same column followed by the same letters are not significantly different at 5% level of significance LSD: Least Significant Difference; CV: Coefficient of Variation Dae: Days After Crop Emergence

Table 6: Main effect of location and weed management practices on number of seeds pod⁻¹ and hundred seed weight of cowpea during 2014 main cropping season.

| Factors | Number of Seeds Pod ⁻¹ | Hundred Seed Weight (G) |
|---|-----------------------------------|-------------------------|
| Location | | |
| Haik | 11.9 | 12.4 ^b |
| Mersa | 11.2 | 12.7 ^a |
| LSD (5%) | 0.70ns | 0.2 |
| Weed management practices | | |
| S-metolachlor at 2.0kg ha ⁻¹ | 11.5 ^c | 12.8 ^{bc} |
| S-metolachlor at 1.0 kg ha ⁻¹ +hand weeding and hoeing 35dae | 14.4 ^a | 14.0 ^a |
| Pendimethalin at 1.0 kg ha ⁻¹ +hand weeding and hoeing 35dae | 13.1 ^{ab} | 13.1 ^b |
| S-metolachlor at 1.0 kg ha ⁻¹ +pendimethalin at 1.0 kg ha ⁻¹ | 11.7 ^{bc} | 12.6 ^{cd} |
| S-metolachlor at 1.0 kg ha ⁻¹ +pendimethalin at 0.75 kg ha ⁻¹ | 11.0 ^c | 12.3 ^d |
| S-metolachlor at 0.75 kg ha ⁻¹ +pendimethalin at 1.0 kg ha ⁻¹ | 10.9 ^c | 12.5 ^{cd} |
| Hand weeding and hoeing 21dae | 10.9 ^c | 12.5 ^{cd} |
| Weedy check | 8.9 ^d | 10.6 ^e |
| LSD (5%) | 1.5 | 0.4 |
| CV (%) | 15.5 | 3.9 |

Means in the same column followed by the same letters are not significantly different at 5% level of significance LSD: Least Significant Difference; CV: Coefficient Of Variation, Dae: Days After Crop Emergence.

However, the differences in effective nodulation might also be due to reduced weed-crop competition, which might have enhanced differential compatibility of effective indigenous Rhizobium association in the soil of the experimental field, as weeds were removed timely. The result of this study is also in agreement with the findings of [26,27]. Research on herbicides showed that many herbicides may affect nodulation by several mechanisms. They can affect plant growth leading to a decreased photosynthate supply to roots and thus decrease the dry weight and available number of infection sites for Rhizobium. Additionally, if a plant is redirecting photosynthate to shoot biomass to facilitate re growth following herbicide injury, less photosynthate is available for rhizobial growth and survival which in turn reduce nodule dry weight and may also directly interfere with rhizobial function and growth [21,22].

The weed management practices revealed that hand weeding and hoeing 3 WAE gave the highest (59.2mg plant⁻¹) nodule dry weight followed by pendimethalin at 1.0kg h⁻¹ supplemented with one hand weeding and hoeing at 5 WAE . Further, the result of weed management practices on nodule dry weight was similar

to their effect on number of effective nodules plant⁻¹ (Table 4). In chickpea, highest number and dry weight of nodules in twice hand weeding at 20 and 40 DAE was followed by herbicide application [28]. On the other hand, in mung bean, maximum number of nodules and nodule dry weight was obtained with complete weed free followed by two hand weeding and herbicide mixtures [29-31].

Effect of weed management practices on yield components and yield

Number of pods per plant: The effect of location, weed management practices and their interaction was significant while planting pattern and other interactions of main factors were not significant on number of pods plant⁻¹ [32]. Stated that the number of pods produced per plant or maintained to final harvest depends on a number of environmental and management practices. The maximum number of pods (31.8 plant⁻¹) was recorded from s-metolachlor at 1.0kg ha⁻¹+ hand weeding 35dae at Mersa which was significantly higher than that was obtained with different management practices at Haik and s-metolachlor at 1.0 kg ha⁻¹+pendimethalin at 0.75kg ha⁻¹ and hand weeding at 21dae at Mersa. . The weedy check plots had lower number of pods plant⁻¹ at both the locations [33]. Also showed that the presence of weeds is effective factor in reducing number of pods in cowpea plant. [34] reported that competition between weeds and crop starts right from germination of the crop up to harvest affecting both growth and yield parameters adversely.

The analysis of variance indicated that the main effect of location and weed management practices had significant

influence on the number of seeds pod⁻¹. The number of seeds pod⁻¹ was higher (11.9) at Haik. Application of s-metolachlor at 1.0kg ha⁻¹ supplemented with hand weeding at 35dae resulted in the highest number of seeds (14.3pod⁻¹) which was significantly higher than the other weed management practices except the application of pendimethalin at 1.0kg ha⁻¹ supplemented with hand weeding at 35dae. Further, the latter treatment had no significant difference with the combined application of s-metolachlor and pendimethalin each at 1.0kg ha⁻¹. The results also revealed that weedy check plots registered significantly lower number of seeds pod⁻¹ than the other treatments. This result agrees with the findings of [35,36], who reported that number of seeds pod⁻¹ was significantly reduced with the increased weed infestation and significantly increased with the weed free period in common bean.

Hundred seed weight: Weight of hundred seeds was significantly influenced by the main effect of location and weed management practices while their interaction was not significant. The 100 seed weight was significantly higher at Mersa than at Haik. The result indicated that the maximum 100 seeds weight was recorded with the application of s-metolachlor at 1.0kg ha⁻¹+ hand weeding and hoeing 35dae (14.0) which was significantly higher than the other treatments. Preemergence herbicides s-metolachlor and pendimethalin had been found to increase 100 seed weight of canola plant [37-39]. It was also found that pendimethalin at 1.0kg ha⁻¹ supplemented with hand weeding at 35dae had no significant difference with s-metolachlor at 2.0kg ha⁻¹.

Table 7: Main effect of location and weed management practices on, grain yield aboveground dry biomass yield and harvest index of cowpea during 2014 main cropping season.

| Factors | Grain Yield (Kg Ha ⁻¹) | Biomass Yield (Kg Ha ⁻¹) | Harvest Index (%) |
|---|------------------------------------|--------------------------------------|-------------------|
| Location | | | |
| Haik | 2714 ^b | 8873 ^b | 30.8 ^b |
| Mersa | 3092 ^a | 9683 ^a | 31.9 ^a |
| LSD (5%) | 116.7 | 350.1 | 1.2 |
| Weed management practices | | | |
| S-metolachlor at 2.0kg ha ⁻¹ | 3169 ^c | 10157 ^a | 31.9 ^c |
| S-metolachlor at 1.0kg ha ⁻¹ +hand weeding and hoeing 35dae | 3960 ^a | 10099 ^a | 40.0 ^a |
| Pendimethalin at 1.0kg ha ⁻¹ +hand weeding and hoeing 35dae | 3462 ^b | 9655 ^{ab} | 36.4 ^b |
| S-metolachlor at 1.0 kg ha ⁻¹ +pendimethalin at 1.0 kg ha ⁻¹ | 3039 ^c | 9473 ^{ab} | 32.5 ^c |
| S-metolachlor at 1.0 kg ha ⁻¹ +pendimethalin at 0.75 kg ha ⁻¹ | 2683 ^d | 8678 ^c | 31.3 ^c |
| S-metolachlor at 0.75kg ha ⁻¹ +pendimethalin at 1.0 kg ha ⁻¹ | 2383 ^e | 9052 ^{bc} | 26.8 ^d |
| Hand weeding and hoeing 21 dae | 3106 ^c | 10063 ^a | 31.4 ^c |
| Weedy check | 1424 ^f | 7043 ^d | 20.5 ^e |
| LSD (5%) | 233.5 | 700.2 | 2.5 |
| CV (%) | 9.9 | 9.2 | 9.8 |

Means in column of same parameter followed by the same letter(s) are not significantly different at 5% level of significance CV: Coefficient Of Variation; LSD: Least Significant Difference; Dae: Days After Crop Emergence; NS: Not Significant

Grain yield: The results indicated that the effect of main factors of location and weed management practices significantly influenced grain yield whereas planting pattern and main factor interaction had no significant effect. The grain yield obtained at Mersa was significantly higher by 13.9 % than at Haik. Among different weed management practices, application of s-metolachlor at 1.0kg ha⁻¹+ hand weeding 35dae recorded significantly higher grain yield (3960kg ha⁻¹) than the other treatments. On the other hand significantly lower yield was obtained in weedy check than the other treatments. Thus the yield obtained in weedy check was 40.2 to 64.0% lower than the other weed management practices (Table 7). These results were in line with the findings of [12] and [40] who reported that 20 to 30% losses in grain yield were quite usual and may increase even 50%, if the crop management practices are not properly followed. Similarly, [16] advocated that pre emergence herbicides provided excellent control of weeds and yield was significantly increased over weedy check. Weeds can severely affect the performance of the cowpea bean and the yield loss was 60 to 66% due to weed interference [41,42] stated that the weeds reduce more than 75% of yield in cowpea crop. However,

the conflicting reports on yield losses due to weeds might be due to the variation in environmental conditions, soil types, the varietal characters and the extent of weed interferences at the locations.

Aboveground dry biomass yield: Analysis of variance showed that the effect of location and weed management practices was significant while planting pattern and the main factor interactions were not significant on above ground dry biomass yield of cowpea. The highest (10157kg h⁻¹) total dry biomass yield was obtained in s-metolachlor 2.0kg h⁻¹ which was not significantly different with s-metolachlor at 1.0kg h⁻¹ + hand weeding and hoeing 35dae, hand weeding and hoeing 3 weeks after crop emergence, pendimethalin at 1.0kg h⁻¹ + hand weeding and hoeing 35dae and s-metolachlor at 1.0kg h⁻¹ + pendimethalin at 1.0kg h⁻¹ weed management practices. [43] reported that the increased dry matter weight of the crop was highly governed by the length of weed free period. However, high production of total dry matter might not necessarily be of great value when the grain comprises a part of the plant. Aboveground dry biomass shows a significant variation across location. Mersa site gave more above ground dry biomass than Haik site.

Table 8: Results of partial budget analysis of weed management practices in cowpea in 2014 cropping season.

| | Average Yield (Kg Ha ⁻¹) | Adjusted Yield (Kg Ha ⁻¹) 10% Down | Total Variable Cost (ETB Ha ⁻¹) | Gross Return (ETB Ha ⁻¹) | Net Return (ETB Ha ⁻¹) |
|---|--------------------------------------|--|---|--------------------------------------|------------------------------------|
| Weed management practices | | | | | |
| S-metolachlor at 2.0kg ha ⁻¹ | 3169 | 2852 | 5687 | 42782 | 37095 |
| S-metolachlor at 1.0kg ha ⁻¹ +hand weeding and hoeing 5 WAE | 3960 | 3564 | 6984 | 53460 | 46476 |
| Pendimethalin at 1.0kg ha ⁻¹ +hand weeding and hoeing 5 WAE | 3462 | 3116 | 6440 | 46737 | 40297 |
| S-metolachlor at 1.0kg ha ⁻¹ +pendimethalin at 1.0kg ha ⁻¹ | 3039 | 2735 | 5695 | 41027 | 35332 |
| S-metolachlor at 1.0kg ha ⁻¹ +pendimethalin at 0.75kg ha ⁻¹ | 2683 | 2415 | 5006 | 36221 | 31215 |
| S-metolachlor at 0.75kg ha ⁻¹ +pendimethalin at 1.0kg ha ⁻¹ | 2383 | 2145 | 4606 | 32171 | 27564 |
| Hand weeding and hoeing 3 WAE | 3106 | 2795 | 6144 | 41931 | 35787 |
| Weedy check | 1424 | 1282 | 2136 | 19224 | 17088 |

Cost of hand weeding and hoeing 2 WAE 45 persons, 5 WAE 16 persons @Birr 33 person-1, ETB=0.0498 USD.

Harvest index

The combined analysis of the experiment data showed that the main effect location and weed management practices had significant effect on harvest index (Table 7). The highest harvest index (31.89 %) was recorded from Mersa, whereas the lowest harvest index (30.77%) was recorded from Haik.

The result indicated there was significant variation on harvest index among the weed management treatments evaluated at both locations. S-metolachlor at 1.0kg ha⁻¹ + hand weeding and hoeing 35dae gave the highest (40.0%) result than the weedy check (20.5%) treatments. [44] reported that the harvest index

of cowpea increases with increasing seed production. This results was also in line with the outcomes obtained by [45] who reported that the effect of s-metolachlor herbicides application on cowpea harvest index was higher.

Partial budget analysis

The result of the partial budget analysis and the data used for the partial budget analysis is given in Table 8 The partial budget analysis was done as described by [10] where the variable costs that vary included the cost of inputs (herbicide) as well as the cost involved in their application.

However, for ease in calculation in place of field price of the crop, the cost incurred for harvesting, threshing, winnowing, packing and transportation was added to the variable input cost. The yield difference per hectare recorded by the different treatments account for the variation observed in value of gross benefit in both locations. The partial budget analysis indicated that the highest gross benefit was obtained from s-metolachlor at 1.0 kg h^{a-1}+ hand weeding and hoeing 5 WAE (53460 ETB h^{a-1}) followed by pendimethalin at 1.0 kg h^{a-1}+ hand weeding and hoeing 5 WAE (46737 ETB h^{a-1}) while the lowest price was recorded from weedy check plots. [46] reported a high economic return with butachlor+one hand weeding in rice while also observed that the use of butachlor took equivalent to 186 hrs while two-hand weeding took 604 hrs ha⁻¹ in rice.

In agreement with the result, most studies showed that, applying herbicide or herbicide plus manual weeding was more economical than manual or hand weeding alone. The result of this experiment indicated that the use of herbicide though reduced the cost of production, the poor control of weeds resulted in significantly low yield compared to the combinations of s-metolachlor at 1.0kg h^{a-1}+hand weeding and hoeing at 35 days after emergence and pendimethalin at 1.0kg h^{a-1}+hand weeding and hoeing at 35 days after emergence. Therefore, managing weeds with the application of s-metolachlor at 1.0kg h^{a-1}+hand weeding and hoeing 5 WAE proved to be most profitable practice.

Conclusion

S-metolachlor 1.0kg h^{a-1} supplemented with one hand weeding 35dae is the most profitable with an alternate weed management option i.e. pendimethalin 1.0kg h^{a-1} supplemented with one hand weeding 35dae. But, managing the weeds with the application of pendimethalin at 1.0kg h^{a-1}+hand weeding and hoeing 35dae proved to be the most profitable practice, since high impact on effective nodulation of s-metolachlor. However, in a situation of unavailability of herbicide on time, hand weeding and hoeing 21dae seemed to be an alternate weed management practice.

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