STUDY ON THE MANUAL, CHEMICAL, CULTURAL AND INTEGRATED WEED MANAGEMENTS IN SOYBEAN

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CERTIFICATE

*This is to certify that the thesis entitled, "**STUDY ON THE MANUAL, CHEMICAL, CULTURAL AND INTEGRATED WEED MANAGEMENTS IN SOYBEAN**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MAQSURUN NAHAR SABA,** Registration no.**19-10271** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date:

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Dedicated to

My

Beloved Parents

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ABSTRACT

During Rabi season, a field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka from December 2021 to April 2022 to study the manual, chemical, cultural, and integrated weed managements in soybean (*Glycine max* L.). The experiment was laid out in randomized complete block design (RCBD) with twelve weed management treatments such as no weeding (Control), two hand weeding (15 and 30 DAS), pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), pre + post-emergence herbicide, pre-emergence + 1 hand weeding {40 days after sowing (DAS)}, Post-emergence + 1 hand weeding (40 DAS), pre + post-emergence + 1 hand weeding (40 DAS), straw mulching, intercrop with red amaranth (*Amaranthus dubius*), intercrop with maize (*Zea mays*), and weed-free. The experimental result showed among seven different weed species found, *Cyperus rotundus* was the most prevalent weed, with the highest weed density (128.67 and 123 m^{-2}) and relative weed emergence (38.79 and 43.16 %) in the weedy check plot at 60 and 90 DAS, followed by *Echinochloa colona* and *Cynodon dactylon*. In comparison, the dominance of *Heliotropium indicum* and *Alternanthera philoxeroides* was the lowest among all weed species in the weedy check plot at 60 and 90 DAS. In case of different weed management treatments, the treatment Pre + Post-emergence + 1 hand weeding (40 DAS) showed the highest pod length (4.16 cm) and seeds pod^{-1} (3.89), while the weed free treatment resulted with the highest 1000 seed weight (111.00 g), seed yield (1.86 t ha^{-1}), stover yield (2.16 t ha^{-1}), biological yield (4.03 t ha^{-1}), harvest index (46.35 %). However, the highest benefit-cost ratio (2.85) was obtained under post-emergence herbicide (Irish @ 1200 ml ha^{-1}) treatment. Therefore, applying post-emergence herbicide (Irish @ 1200 ml ha^{-1}) will be the best weed management practice for profitable soybean cultivation.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is the most widely cultivated legume around the world because of its versatile uses and economic importance (Liu *et al.,* 2020). It is one of the most multipurpose, nutritionally, and economically important legumes due to its unique seed composition (Shea *et al*., 2020). Soybean seed contains about 18 to 22% oil and 38 to 56% vegetable protein with favorable amino acids (USDA, 2018). It is a prominent source of proteins and edible oil and has practical uses as food, feed, and oil seed crop (Liu *et al*., 2020). Globally, soybean is responsible for about 61% of total international oilseed production, occupying 6% of the world's cultivable area (SoyStat, 2019). According to USDA (2021), about 391.40 million tons of soybean are produced around the world from a cultivated area of 121.69 million hectares with an average yield of 2.76 t ha^{-1}. The United States, Brazil, and Argentina are the leading soybean-producing countries in the world and are responsible for 81% of the total production.

In Bangladesh, 0.986 million tons of soybean were produced on 59,445 hectares of land, while global production was 391.40 million tons in 121.69 million hectares (USDA, 2021). BBS (2021) reported that the total soybean cultivated area was 57646.26 hectares, and the whole production was 91176.59 tons in Bangladesh. Our country's demand for soybean as poultry feed was 1.8-2 million tons in 2021 (BBS, 2021).

Soybean oil has gained popularity in modern-day cooking in Bangladesh. However, as its extraction from soybean seed is not yet possible using traditional methodologies, most of the soybean that the country produces is used predominantly in the feed industries, and any soybean oil in the market is imported. Around 1942, soybeans were introduced to Bangladesh, but until 1960–1961, no significant efforts were made to popularize the crop or to carry out research on it. The Mennonite Central Committee (MCC) reintroduced soybean to Bangladesh in 1972-1973 (MCC, 1982). Its cultivation has not been taken off more quickly because of disease infestation, low yield, delayed maturity, and highly shattering pods. Growing numbers of farming households in the nation's southern region are turning to soybean as a cash crop (Noakhali, Lakshmipur, and Bhola districts). The development of small soy-based food manufacturing companies, which produce milk, curd (yogurt), flour/bread, meat, halwa, biscuits, and various snacks, could potentially improve the socioeconomic situation of these farming communities..

Both at the national and zone level, soybean's low productivity is attributed mainly to biotic and abiotic stresses, *viz.,* weeds, insect pests, and disease (Chaudhari *et al*., 2020). Weeds are misfits and one of the major limiting factors of soybean production worldwide. The losses caused by weeds and the cost of weed control are among the most expensive items in crop production. The initial growth of soybean is slow, and the crop faces severe competition from weeds. The first 30 days after the sowing of soybean is considered to be critical concerning weed-crop competition. Heavy infestation of weeds leads to a reduced yield, and quality is also affected adversely (Tehulie *et al*., 2021). Almarie (2017) concluded that the critical period of crop weed competition in soybean is reported to be the first 45 DAS. Sandil *et al.* (2015) reported that weeds alone are responsible for reducing soybean seed yield to 25 to 70% depending upon the weed flora and intensity.

Many kinds of weeds have different life cycles; thus, a single control method is ineffective. In addition, controlling weeds in one or two ways provides the weeds a chance to adapt to those practices. Therefore, instead of using a particular weed control method, IWM suggests using a mixture of control methods that minimize the economic impact of weeds. Applying the principles of IWM can reduce the use of herbicides applied to the environment and, at the same time, provide optimum financial returns to the producers.

Chemical weed control has been a primary means of weed management in the developed world for the past six decades. In Bangladesh, most farmers use pre-and post-emergence herbicides for weed control, but their efficacy is reduced by various climatic and edaphic factors (Ahmed and Chauhan, 2014). The herbicides presently available are either pre-emergence (PE) or pre-plant incorporated (PPI) and have a narrow spectrum of weed control(Chaudhari *et al*., 2020). Even with herbicide-tolerant crops (HTCs), representing relatively new weed control technology remains true. Examples of HTCs include soybean (*Glycine max* L.), corn (*Zea mays* L.), and canola (*Brassica napus* L.), tolerant to glyphosate and glufosinate.

As a consequence of herbicide use, the presence of residues in the field may cause damage to succeeding crops. Herbicide residues also remain on the soil surface due to the adsorption process, which may affect the quality and yield of succeeding crops cultivated in the same field. Hand weeding is a traditional and effective method of weed control. Still, untimely continuous rains during critical weed competition periods, unavailability of labor at peak times, and increased labor wages are the main limitations of manual weeding. Under this situation, an integrated weed management (IWM) practice involving both chemical and other agronomic manipulation may be an efficient tool, as increasing crop density seems to be an alternative to shift crop-weed competition in favor of crop (Velmurugan *et al*., 2018).

The use of integrated control facilitates weed control during all crop cycles. The integrated weed management (IWM) approaches incorporate multiple tactics of prevention, avoidance, monitoring, and suppression of weeds, undergirded by the knowledge of agroecosystem biology (Scavo and Mauromicale, 2020). The development of IWM was motivated by a desire to provide farmers with systematic approaches to reduce reliance on herbicides (Knezevic, 2014) and, consequently, retard the selection of herbicide-resistant biotypes.

Hence, the present investigation was conducted to study the soybean yield as influenced by weed management practices and its carryover effect on follow-up crops by observing the following objectives-

i. To study on the weed dynamics in soybean.
ii. To observe the efficacy of pre and post-emergence herbicides on weed control, crop growth, and yield
iii. To Evaluate the intercropping practice in soybean cultivation for suppressing weeds
iv. To find out the efficacy of different weed management practices on the growth and yield of soybean.
v. to work out the economics of different weed management practices in soybean.

CHAPTER II

REVIEW OF LITERATURE

Weeds is a severe problem in all crops, but they are even more in Rabi crops like oilseeds (soybean). Several researchers worldwide have tried to tackle this problem with various weed control methods and obtained varying degrees of success. Therefore an effort was made to compile and research pertinent material about the soybean yield as influenced by weed management practices type of work done in Bangladesh and abroad is being dealt with in this chapter.

2.1 Weed flora in soybean

Bhimwal *et al.* (2017) reported that the experimental field of soybean was mainly infested with *Commelina benghalensis* (42.56 and 52.26%), *Digera arvensis* (12.45 and 9.45%), *Trianthema portulacastrum* (18.39 and 17.55%), *Echinochloa colona* (17.04 and 15.02%), and *Cyperus sp.* (9.56 and 5.42%) during 2015 and 2016, respectively. Lal *et al.* (2017) observed that the soybean experimental field was infested with monocot weeds. *E. colona* (29.28%), *Dinebraret roflexa* (35.85%), *C. iria*(1.65%) and dicot weeds like *Euphorbia geniculata* (24.67%), *Phyllanthus niruri* (8.53%) and *C. benghalensis* (2.63%).

Dhaker *et al.* (2016) showed that the weed flora during the study period constituted monocot weeds were *E. colona* (53%), *C. dactylon* (2.5%), *and C. rotundus* (3.75%) while dicot weeds were *Trianthema portulacastrum* (8.25%), *C. benghalensis* (L.) (9.0%), *Amaranthus spinosus* (L.) (8.5%), *D. arvensis* (11.0%)and *Parthenium hysterophorus* (7.0%). Overall, the experiment was dominated by the density of monocot weeds, especially *C. rotundus* and *E. colona*. Kheriya *et al.* (2016) reported that in the experimental field, *E. colona* (35.77%) was the rampant weed, closely followed by *Dinebra retroflexa* (25.97%). However, other monocot weeds like *C. iria* (12.58%) and *Cynodon dactylon* (8.34%) and dicot weeds like *Alternanthera philoxeroides* (8.78%) and *Eclipta alba* (8.56%) were also present in fewer numbers with soybean in weedy check plots. Singh *et al.* (2016) enquired about major weed species within the experimental soybean plots were *C. rotundus*, *C. iria* (sedges), *C. dactylon*, *Dactyloctenium aegyptium*, *E. colona*, *E. crus-galli* (grasses), *Ageratum conyzoides*, *Amaranthus viridis*, *Celosia argentea*, *C. benghalensis*, *Digerati arvensis*, *E. hirta*, *Portulaca oleracea*, *Tridex procumbens* and *Xanthomonas strumarium* (broad-leaved weeds). Among discontinuous categories, broadleaved weeds were recorded in higher numbers, followed by grasses and sedges.

According to Panda *et al.* (2015), grassy weeds were predominant (76.28%) in an experimental field as compared with broad leaves weeds (23.73%). However, in soybean, *E. colona* (34%) and *Dinebraret roflexa* (25%) were predominant. Still, other weeds like *C. rotundus* L., *C. dactylon* L., *Alternanthera philoxeroides* L., *E. alba* L. and *Mollugo pentaphylla* L. were also present. Premchand *et al.* (2015) depicted different dicot weed species within the experimental field *Lagasca mollis* L., *E. hirta* L., *Digera arvensis* L., *Tridex procumbens* (L.), *P. hysterophorus* (L.), *Celosia argentea* (L.), *Euphorbia geniculata* L., *Alysicarpus rugosus* L., *Alternanthera triandra* L., etc. Different monocot weed species observed were *Dinebra Arabica* (L.), *E. crusgalli* L., *Eragrostis major* (L.), *C. dactylon* L., *C. iria* L., *etc*. Sandil *et al.* (2015) reported that weed species identified within the experimental field were monocot weeds *C. rotundus* (25.8 and 23.6%) followed by *E. colona* (23 and 24 %) and *C. benghalensis* (15.6 and 18%). Besides these dicots, weeds *E. alba* (19.1 and 20.3%) and *A. philoxiroides* (16.4 and 14.9%), were also found in the soybean ecosystem at 45 DAS and harvest stage, respectively**.**

Chander *et al.* (2013) at Palampur (H.P) reported that the soybean field was infested with *C. benghalensis, E. colona, Aeschynomene indica, Ageratum conzoides, Panicum dichotomiflorum, Digitaria saniguinalis, Eleusine indica, and Cyperus sp.*

2.2 Effect of weed management practices on weeds

Nagre *et al.* (2017) conducted a field experiment at Rahuri (Maharashtra) with the application of pendimethalin (PE) at 0.75 kg ha^{-1} followed by one-hand weeding at 30 DAS and pendimethalin (PE) at 0.75 kg ha^{-1} followed by tank-mix imazethapyr + propaquizafop (80 and 60 g ha^{-1}) at 25 DAS recorded significantly lowest total weed count, weed dry matter and weed index with higher WCE, herbicide efficiency index, crop resistance index and higher soybean grain, straw yield, net returns, and B: C ratio. Imazethapyr's a selective pre-emergence, early post-emergence, and post-emergence herbicide recommended for selective weed control in soybean, groundnut, etc. Patil *et al*. (2017) indicated that the integration of herbicides like pendimethalin at 0.75 kg ha^{-1} PE + 1 HW and inter-cultivation at 20 DAS recorded significant lowest weed dry matter and better weed control efficiency leading to a higher yield of soybean.

Kumar *et al.* (2016) found that pre-emergence application of pendimethalin @ 1 kg ha^{-1} supplemented with post-emergence application of bispyribac-sodium @ 30 g/ha at 20 DAS and hand weeding reduced the seed sterility percentage and increased the leaf area index, chlorophyll content and photosynthetic rate of soybean. Parmar *et al.* (2016) observed a field experiment conducted in Madhya Pradesh and found that the maximum Net Monetary Return (NMR) was under imazethapyr + imazamox, and weed control efficiency (WCE) was recorded to be 82.4 percent in soybean. Rai *et al*. (2016) observed the effect of pre-emergence herbicides (pendimethalin and oxiflourfen), post-emergence herbicides (imazethapyr), and their combinations in pigeonpea + greengram or pigeonpea + blackgram intercropping system, that among herbicide treatments significantly higher weed controlling efficiency was recorded in pendimethalin + imazethapyr and oxyflourfen + imazethapyr (90.6 - 91.5%) as compared to pendimethalin or oxiflourfen or imazethapyr (72.1 - 84.6%) alone. Singh *et al.* (2016) reported that the single application of pre-emergence (oxadiargyl) or post-emergence (bispyribac-sodium) herbicides had 16 and 11 broadleaved weeds m^{-2}, respectively. They provided 27-614 reduction in total weed density compared to a 64-82% reduction in total weed density obtained with sequential application of pre-emergence fb. post-emergence herbicides. Yadav (2016) reported that weed intensity at 14, 28, and 42 DAS, and at harvest was significantly lower in weed-free check over the rest of the treatments. It was followed by pendimethalin @ 1 kg a.i. ha^{-1} fb. one hoeing at 30 DAS. The weedy treatment check recorded the highest weed intensity and weed dry matter as compared to other treatments. The treatment weed-free check controlled the weeds to 89.18 percent and pendimethalin @ 1 kg a.i. ha^{-1} fb. one hoeing at 30 DAS managed the weeds to 77.52 percent over the weedy check.

Awan *et al.* (2015c) found that all herbicide treatments involving sequential application of pre-emergence and post-emergence herbicides reduced total weed density by 85-100% and biomass production by 80-100%, whereas late post-emergence treatments reduced total weed density only by 32-50% and biomass production by 40-62% as compared to the unweeded control. Kailkhura *et al.* (2015) suggested the sequential application of pendimethalin (1 kg/ha) as pre-emergence fb. post-emergence application of bispyribac-sodium (25 gha^{-1}) or post-emergence application of ready-mix of penoxsulam + cyhalofop-butyl (130 g/ha) was found most effective in controlling complex weed flora in direct-seeded rice and recorded highest weed control efficiency. Rao *et al*. (2015) reported that the integration of one-hand weeding/inter cultivation at 50 DAS with pendimethalin @ 0.75 kg *a.i.* ha^{-1} PE or imazathapyr @ 100 g *a.i* ha^{-1} POE or quizalofop ethyl @100 *a.i.* ha^{-1} POE or pendimethalin @ 0.75 kg *a.i.* ha^{-1} PE and imazathapyr @ 100 g *a.i.* ha^{-1} POE proved effective in reducing total weed density and dry weight of weeds and also increased weed control efficiency compared with weedy checks.

In a field experiment at Oilseeds Research Station, Latur, Habimana *et al.*(2013) found that among the weed control treatments, significantly lower total weed density was recorded at harvest under inter-cultivation fb. twice hand weeding at 20 and 40 DAS (8.00 per 0.25 m^2) and remained at par with metribuzin at 500 g ha^{-1} at 3 DAS *fb*. imazethapyr at 100 g ha^{-1} at 20 DAS (8.67 per 0.25 m^2). Similarly, significantly lower total weed dry weight (1.00 g 0.25 m^2), as well as more than 96 percent weed control efficiency, were recorded in inter-cultivation fb. two hand weeding.

Malviya *et al.* (2012) at Faizabad, Uttar Pradesh observed that all weed control treatments effectively controlled weeds compared to weedy check in maize + blackgram intercropping system. The highest weed control efficiency (WCE) was recorded under weed-free treatment (100%), followed by two-hand weeding at 20 and 40 DAS (66.2%) and pre-emergence application of alachlor @ 2.0 kg ha^{-1} + HW at 30 DAS (62.1%). Among pre-emergence herbicides, alachlor was most effective against weeds (52.8%) followed by pendimethalin (46%) and atrazine (39.9%).

Chandolia *et al.* (2010), during a field experiment on groundnut at Udaipur during *Kharif*, revealed that application of pendimethalin 1.0 kg ha^{-1} as pre-emergence one-hand weeding at 30 DAS significantly reduced the weed density and their dry matter compared to the weedy check.

Girothia and Thakur (2006) at Indore observed that application of post-emergence herbicides i.e. imazamox + imazethapyr @ 800-1000 ml ha^{-1} or imazethapyr @ 75-100 g a. i. ha^{-1} at 25 DAS was found as effective as weeds free or check herbicide those were, reflected in higher weeds control efficiency, lower weeds index and enhanced seed yield over the weedy check.

2.3 Effect of weed management practices on the growth and yield of soybean

Qin *et al.* (2022) reported that intercropped soybean with maize showed a higher nodule dry weight $plant^{-1}$ and N_2 fixation efficiency under low P availability than mono-cropped soybean as evidenced by improvement in the number, dry weight, and nitrogenase activity of nodules.

Karimi *et al*. (2021) reported that the fresh weight of *Satureja hortensis* under different treatments of weeding times and densities, except for 125 plants m^{-2} was more than the weedy check. The highest fresh weight was related to 75 plants m^{-2} with weeding four times in the amount of 8140 mg $plant^{-1}$. The difference with 50 plants in the same number of hand weeding times was not significant.

Mengistu and Mekonnen (2020) reported that the highest weed control efficiency was obtained from 30 cm × 10 cm plant spacing and twice hand weeding and hoeing at 2 and 5 WAE (Weeks after crop emergence). The significantly higher number of pods per plant (20.38) and seeds pod^{-1} (11.68) of mungbean was obtained from weed-free checks. The highest grain yield of 1412.9 kg ha^{-1} and the harvest index of 42.94% were obtained from weed-free checks.

Kumar *et al.* (2019) conducted research at Rajasthan Agricultural Research Institute (RARI), Durgapura (Rajasthan), and observed that in the case of a greengram the highest pods/plant, seed pod^{-1}, test weight (g), and grain yield (q ha^{-1}) were recorded under two hand weeding (HW) at 20 and 40 DAS (19.33, 9.66, 38.49 and 6.8, respectively) which was on par with manual weeding at 25 DAS (18.66, 9.33, 37.96 and 6.5, respectively). This might be due to a reduction in weed growth and the population at different stages and lower competition by weeds with the crop for moisture and nutrients.

Gidesa and Kebede (2018) revealed that in weedy check plots, 77.6% to 78.50% seed yield reduction in soybean was observed. These seed yield reductions can be reduced by using herbicides followed by hand weeding to manage weeds in soybean effectively.

Kamble *et al.* (2017) reported that among the weed management treatments weed-free treatment recorded significantly higher soybean seed yield (2.19 t ha^{-1}) and stover yield (2.71 t ha^{-1}) but was at par with treatments Pendimethalin 38.7% CS (PE) at 0.75 kg ha^{-1} followed by one hand weeding at 30 DAS (2.71 t ha^{-1}), respectively and Pendimethalin 38.7% CS (PE) at 0.75 kg ha^{-1} followed by tank-mix Imazethapyr 10% SL + Propaquizafop 10 domestic science at 80 60 g ha^{-1} at 25 DAS, (2.70 t ha^{-1}) respectively. According to Kulal *et al.* (2017), the post-emergence application of Imazethapyr 75 g ha^{-1} at 21 DAS recorded the highest number of pods $plant^{-1}$ (38.25), the number of grains pod^{-1} (2.14), seed weight $plant^{-1}$ (09.86 g), 100 seed weight (12.05 g), seed yield (2705 kg ha^{-1}) and stover yield (3416 kg ha^{-1}) as compared to other herbicidal treatments. Mondal *et al*. (2017) experimented during the summer of 2014-15 and 2015-16 at a farmer's field, Nadia, West Bengal on groundnut (JL-24) and soybean (PK-327) to find out the effect of imazethapyr10 SL @ 100 g ha^{-1}, quizalofop-ethyl 5 EC @ 50 g ha^{-1}, fenoxaprop-p-ethyl 9 EC @ 50 g ha^{-1}, oxyfluorfen23.5 EC @ 200 g ha^{-1} and tank mixture of Calotropis + Parthenium raw leaf extract 5% @ 100 ml $liter^{-1}$ of water on root nodulation and economic yield compared with hand weeding and weedy check. Results revealed that the number of nodules $plant^{-1}$ at 25 and 45 DAS got affected immediately after the herbicide application. This may be due to the inhibition effect of chemical herbicides on rhizobium population, which decreased the nodule formation. Application of botanicals showed lesser harmful effects on nodule number in both crops. Pre-emergence application of Oxyfluorfen 23.5 EC @ 200 g ha^{-1} recorded 0.83-18.45% and 1.12-7.78% higher seed yield in groundnut and soybean crops, respectively than the tested post-emergence herbicides. It may therefore be concluded that weed management by eco-safe pre-emergence herbicides, especially botanicals at critical crop weed competition periods, helps to increase the production as well as root nodulation of legume oilseeds. Raghavendra *et al*. (2017) carried out a study on the impact of post-emergence herbicides on soil microorganisms, nodulation, and yield of chickpea and observed that the nodule number of chickpea, is generally found to vary at different stages (30, 60 DAS and at harvest) of the crop growth. Among the treatments, more nodules were noticed in the plots where herbicides were not imposed in plots (weed-free and weedy check plots) when compared with different pre, and post-emergence herbicides imposed plots. The nodule number per plant was recorded and found to be highest at 60 DAS. At 30 DAS, observations of nodule number at 30 days after sowing ranged from 17 to 37 per plant and were noticed highest in weed-free (37 per plant). At the same time, the lowest nodules plant^{-1} were noticed in the weedy check. Among herbicides, more nodules were observed in phenaxoprop ethyl treated plots (24 plant^{-1}), and less number of nodules (20 per plant) were noticed in oxyfluorfen treatment.). Sharma *et al.* (2017) conducted a field experiment on soybean and concluded that pre-emergence application of pendimethalin 750 g ha^{-1} in conjunction with hand weeding 30 DAS recorded the seed yield of 1.38 t ha^{-1} at par with hand weeding twice (1.32 t ha^{-1}) as well as weed-free treatment (1.42 t ha^{-1}).

Dhakad *et al*. (2016) found that post-emergence (20 DAS) application of Imazethapyr at 100 g ha^{-1} hoeing & weeding at 40 DAS recorded a significantly higher seed yield (1395 kg ha^{-1}) that was 195.7 percent more than the weedy check. Pandit *et al*. (2016) at Gulbarga reported that the pre-emergence application of pendimethalin @ 0.75 kg *a.i*ha^{-1} – one hand weeding at 50 DAS recorded significantly higher weed control efficiency (97.4%) similar to that of weed free plot (97.4%) and was on par with hand weeding twice at 25 and 50 DAS (94.2%) at 70 DAS. Application of imazethapyr @ 75 g *a.i.* ha^{-1} at 20 DAS, paraquat @ 0.40 kg *a.i.* ha^{-1} at six weeks after sowing recorded significantly higher seed yield, more number of pods per plant, pod weight, and 100 seed weight as compared to other treatments. Significantly lower seed yield and yield parameters were recorded in weedy check treatment because of higher weed incidence and their competition throughout the growth period of pigeonpea. It can be concluded that Imazethapyr @ 75 g *a.i.* ha^{-1} at 20 DAS, paraquat @ 0.40 kg *a.i*. ha^{-1} at six weeks after sowing can be effectively used for controlling weeds and in obtaining the optimum seed yield of pigeonpea. Yadav *et al.* (2016) reported that the yield contributing characteristics like number of seeds pod^{-1}, number of pods plant^{-1}, the weight of pods plant^{-1}, 1000 seed weight, seed, and stover yield was found significantly superior in weed-free check followed by pendimethalin @ 1 kg a.i. ha^{-1} fb. one hoeing at 30 DAS.

Suryavanshi *et al*. (2015) reported that the highest yield attributing traits and yields of sunflower were recorded in the weed-free situation, but these parameters were found statistically at par with the application of pendimethalin0.75 kg ha^{-1} (PE) + one hoeing at 30 DAS followed by hand weeding at 40 Days after sowing and application of pendimethalin1.0 kg ha^{-1} (PE) + quizalofop-ethyl 37.5 g ha^{-1} at 20 DAS. Susmita *et al*. (2015) conducted a field experiment at the Product Testing Unit, JNKVV, Jabalpur during *Kharif* season in 2013 and 2014 to adjudge the efficacy of propaquizafop and imazethapyr mixture against weeds in soybean and observed that post-emergence application of propaquizafop (75 g ha^{-1}) alone curbed only grassy weeds. However, its efficacy was improved when applied in combination with imazethapyr being higher under propaquizafop + imazethapyr mixture used at 53 + 80 g ha^{-1} or higher rate (56 + 85 g ha^{-1}). Yield attributing characters and yield were superior under propaquizafop + imazethapyr mixture applied at 56 + 85 g ha^{-1} followed by 53 + 80 g ha$^{-1,}$ which were comparable to hand weedings twice at 20 and 40 DAS.

Gore *et al.* (2014) at Parbhani (Maharashtra) reported that weed-free check treatment recorded the lowest dry weight (monocot and dicot) than the rest of the treatments. Among the herbicides, pendimethalin @ 750 g ha^{-1} (PE) + 1 HW and imazethapyr @ 75 g ha^{-1} (POE) were found efficient in managing both types of weeds. The treatment weed-free check (2 hand weeding + 2 hoeing 3rd and 5th recorded the highest seed yield ha^{-1}. However, it was at par with treatment pendimethalin @ 750 g ha^{-1} (PE) + 1 HW at 30 DAS and imazethapyr 75 g ha^{-1} (POE) at 21 DAS and tank mix quizalfop-ethyl @ 40 g ha^{-1} (POE) + chlorimuron-ethyl @ 12 g ha^{-1} (POE) at 20 DAS. Jha *et al.* (2014) reported that the weed-free check was found the best by recording the highest nodulation, yield, yield attributes, N uptake, and soil parameters. Singh *et al.* (2014) conducted a field experiment during Kharif 2008 and 2009 at the experimental area of Punjab Agricultural University, Ludhiana, on mungbean recorded maximum plant height, crop dry matter, and the number of leaves under two-hand weeding, which was significantly higher than other weed management treatments. Zaher *et al.* (2014) also reported that harvest index was lower in weedy check treatment.

Jadhav (2013) at Karad and Satara, Maharashtra reported that integrated weed management treatments, i.e., quizalofop-ethyl 0.05 kg ha^{-1}and chlorimuron-ethyl 0.009 kg ha^{-1}as post-emergence at 15 DAS + hand weeding at 30 DAS, recorded significantly higher plant height, pods plant^{-1}, less weed biomass, and higher seed and straw yield (3423 and 2448 kg ha^{-1}) of soybean. Nainwal *et al*. (2013) conducted a field experiment during the Kharif2008 and 2009 to assess the efficacy of different herbicides on weed infestation and seed yield of soybean [*Glycine max* (L.)]. and observed that the highest weed control efficiency and the lowest weed biomass were recorded in weed-free treatment followed by the application of diclosulam 18 g ha^{-1} as pre-emergence with one-hand weeding at 20 DAS. Peer *et al.* (2013) conducted two field experiments at the experimental farm of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus in the *Kharif* seasons of 2004 and 2005 to study the effect of various weed control methods on yield and yield attributes of soybean. All weed control measures registered significantly higher seed yields of soybean than weedy check. However, weed-free treatments, hand weeding twice, and both fluchloralin and pendimethalin integrated with hand weeding recorded far superior yields of soybean seed. Integrated use of herbicides gave better seed yield than their application. Younesabadi *et al*. (2013) reported that all weed control treatments gave significantly higher soybean seed yield compared to weedy check, but pendimethalin (0.75 kg *a.i*ha^{-1}) + imazethapyr (0.75g *a.i*ha^{-1}) as POE was comparable with a weed-free check and was superior to all other weed control treatments.

Eldabaa *et al.* (2012) reported that herbicides could affect the formation and growth of root hairs of soybean, which in turn affects the process of infection by nitrifying bacteria. The herbicide applied at the recommended rate for a legume crop would be fairly nontoxic to the plant, but possible toxic effects on the rhizobium bacteria or the nodulation process may occur. The lack of inhibitory effect of an herbicide on nodulation could be due to its rapid inactivation in soil or its rapid translocation, along with photosynthate, to a distant metabolic sink resulting in low dry matter weight of nodule. Mochiah *et al.* (2012) reported in the experiment on chili, and the results indicated that straw mulch enhanced plant height, number of leaves plant^{-1}, increased fruit number and percentage yield while live-mulch of cowpea and plastic mulch reduced plant height, number of leaves plant^{-1}, fruit number and percentage yield.

Meena *et al*. (2011) conducted a field experiment at Kota and observed that the maximum seed and haulm yield, as well as harvest index of 1075 kg ha^{-1}, 1709 kg ha^{-1}, and 38.6 %t, respectively, were recorded under weed-free treatment, and this treatment was significantly superior to rest of the treatment.

Chandolia *et al.* (2010), during a field experiment on groundnut at Udaipur during Kharif, revealed that application of pendimethalin 1.0 kg ha^{-1} as pre-emergence one-hand weeding at 30 DAS significantly reduced the weed density and their dry matter compared to the weedy check. They further reported that this treatment also recorded the highest dry matter accumulation plant^{-1}, plant height, pod yield, total N and P uptake, and B: C ratio, juxtaposed to the remainder of the treatments under test.

Koodi (2010) noticed the highest number of leaf plant^{-1} (at 40 DAS) with two-hand weeding (20 & 40 DAS) (36.03 leaves) closely followed by imazethapyr 125 g ha^{-1} (20 DAS) (34.71 leaves) and imazethapyr 75 g ha^{-1} (20 DAS) (29.30 leaves).

Venkatesha *et al*. (2008) reported that post-emergence application of imazethapyr 75 g/ha alone and with hand weeding was most effective in minimizing weed growth and enhancing soybean grain yield. The yield under weed-free treatment was similar to that of imazethapyr 75 g ha^{-1} alone and with hand weeding and imazethapyr 100 g ha^{-1}. The phytotoxicity symptoms on crops were not observed in soybean due to the application of imazethapyr.

Virkar *et al*. (2007) conducted a field trial on pigeonpea during *Kharif* 2003 on clay loam soil. They reported that yield losses due to weeds infestation in pearl millet + pigeonpea intercropping had been around 70-79 %.

Singh *et al.* (2005) at Udaipur reported that in the maize + soybean intercropping system, all weed control methods significantly enhanced the growth and grain yield of maize, soybean as well as maize equivalent yield. Alachlor and pendimethalin supplemented with one hoeing at 25 DAS were superior. The extent of increase in maize equivalent yield by alachlor and pendimethalin integrated with one hoeing was by 60.3 and 54.6

percent, respectively, over the weedy check. Reduced crop-weed competition under alachlor along with hoeing and pendimethalin hoeing during the critical phase of crop growth, increased yield.

Based on the above review, it is delineated that integrated weed management on soybean plays a significant role in successful soybean production. Therefore the present was conducted to study on the manual, chemical, cultural and integrated weed managements in soybean

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to study the manual, chemical, cultural, and integrated weed managements in soybean. The materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during December 2021 to April 2022 of the *Rabi* season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted in the Central laboratory and the Sher-e-Bangla Agricultural University (SAU) Agronomy field. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meters above sea level.

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agroecological zone (AEZ) of “The Modhupur Tract,” AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract, leaving small hillocks of red soils as ‘islands’ surrounded by the floodplain. Appendix-I shows a better understanding of the experimental site in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil texture was silty clay with a pH of 5.6. The morphological, physical, and chemical characteristics of the experimental soil have been presented in Appendix-II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February, the pre-monsoon period or hot season from March to April, and the monsoon period from May to October (Shahid, 2010). Meteorological data related to the temperature, relative humidity, and rainfall during the experiment period was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Experimental material

Binasoybean-2 was used as experimental material for this experiment. The important characteristics of the Binasoybean-2 variety was mentioned below:

Binasoybean-2

Binasoybean-2 was developed by the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh, through mutation breeding and released in 2011. The plant is shorter in height with deep green leaves; the hylum is very clear and black and has a bright yellow seed coat color. This variety can be grown in both *Kharif* (mid-July) and *Rabi* (mid-January) seasons. The maturity period ranges from 110-115 days. It can be grown in a wide land and soil types, from sandy to loam soils. This variety can be cultivated all over the country but is more suitable for high and Charland of South and South-western regions of Bangladesh. Binasoybean -2 is tolerant to the yellow mosaic virus(YMMV). It can produce a seed yield of 2.4-2.8 t ha^{-1}.

3.4 Land preparation

Initially, the field was prepared with the help of a tractor-drawn implement. After giving one deep ploughing the experimental area was cross-harrowed and leveled adequately to break the clods and bring the soil to the desired tilth. The plots were prepared manually for sowing of seeds of the subsequent crops of the experimental study. Land preparation was done on 25 December 2021.

3.5 Experimental treatment

There was a single factor in this experiment comprising manual, chemical, cultural, and integrated weed managements as follows:

T_1: No weeding (Control),

T_2: Two-hand weeding (15 and 30 DAS),

T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1})

T_4: Post-emergence herbicide (Irish @ 1200 ml ha^{-1})

T_5: Pre + Post-emergence herbicide

T_6: Pre-emergence (Herbilin 33% EC @ 400 ml ha^{-1}) + 1 hand weeding (40 DAS),

T_7: Post-emergence (Irish @ 1200 ml ha^{-1}) + 1 hand weeding (40 DAS,

T_8: Pre + Post-emergence + 1 hand weeding(40 DAS),

T_9: Straw mulching,

T_{10}: Intercrop with red amaranth,

T_{11}: Intercrop with maize and

T_{12}: Weed-free.

3.6 Experimental design and layout

The experiment was laid out in a randomized complete block design with three replications. There were 12 treatments and 36 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.The layout of the experimental field was done on 25 December 2021 and is shown in Appendix -IV.

3.7 Seed collection

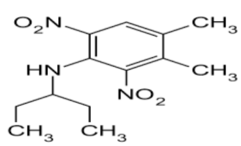
For the present experiment, the seeds of the test crop, i.e., Binasoybean-2 were collected from the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh.

3.8 Fertilizer management

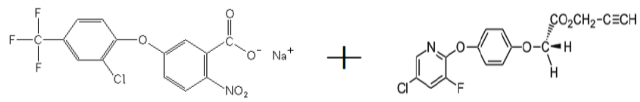
Urea, TSP, MoP, Gypsum, and boric acid were used as the source of Nitrogen, Phosphorus, Potassium, Sulphur, and Boron respectively were applied @ 50, 150, 100, 80, and 8 kg ha^{-1}. All the fertilizers were used as basal application during final land preparation. (BARI, 2019)

3.9 Description of the herbicides (Herbilin and Irish) used for weeds control in the experimental field

<u>Pendimethalin</u>

Trade name	Herbilin 33% EC
Name of registration holder	Aranya Crop Care Ltd
IUPAC Name	[N-(l-ethylpropyl)-3, 4-dimethyl 1, 2, 6Dinitrobenzenamine]
Structural formula	
Molecular weight	281.31.
Formulation types	Emulsifiable concentrate (EC)
Mode of actions	Pre-emergence herbicide. Inhibits root and shoot growth. It also prevents weeds from emerging.
Target Weeds	*Echinochloa crusgalli, E. colona, Brassica kaber, Cyperus rotundus, Cynodon dactylon, Alternanthera philoxeroides, Heliotropium indicum, Enydra fluctuans etc.*
Major crops	Potato, Onion, Garlic, Maize, and Soybean.
Application rate	400 ml ha^{-1}.
Time of application	Two days after sowing

IRIS Sodium Acifluorfen 16.5% + Clodinafop Propargyl 8% EC

Trade name	IRIS
Name of registration holder	United Phosphorus Limited.
IUPAC Name	Sodium Acifluorfen 16.5% + Clodinafop Propargyl 8% EC
Structural formula	
Molecular weight	383.64 g mol^{-1}
Formulation types	Emulsifiable concentrate (EC).
Mode of actions	Clodinafop- Acetyl CoA Carboxylase (ACCase) Inhibitor. Acifluorfen Cell membrane disruption - PPO inhibitor (Protoporphyrinogen oxidase).
Target Weeds	Iris is a contact and systemic for a wide range of weed controls. *Alternanthera philoxeroides, Amaranthus spp, Celosia argentea, Cleome viscosa, Commelina benghalensis, Digera arvensis, Digitaria sanguinalis, Echinochloa spp, Eleusine indica, Euphorbia spp, Parthenium spp, Phyllanthus niruri, Physalis minima, Stellaria media, Trianthema monogyna, Acalypha indica, Dactyloctanium aegyptium,* (Broad leaf weeds).
Major crops	A broad-spectrum herbicide for post-emergence weed control in soybean, groundnut, and cowpea.
Application rate	1200 ml ha^{-1}
Time of application	It is exclusively a post-emergence herbicide and it can effectively control a broad spectrum of weeds. Applied 2-3 weeks after sowing.

3.10 Seed sowing

Seeds were sown by dibbling in soil. The dribbling was done by maintaining a 45 cm inter-row and 5 cm intra-row distance and 30 cm inter-row and 10 cm intra-row distance. It was done on 26 December 2021.

3.11 Application of pre-emergence herbicides

The herbicide, viz., Herbilin 33% EC @ 400 ml ha^{-1}was sprayed two days after sowing as per treatments by using hand operated knapsack sprayer fitted with a flat fan nozzle.

3.12 Straw mulching

While sowing of seeds, straw mulching was given around the plot as per treatment requirements.

3.13 Intercropping

For intercropping, maize and red amaranth seeds were also sown according to per treatment requirement, and it was sown on 26 December 2021.

3.14 Germination of seeds

After the sixth day of seed sowing, the seed began to germinate. More than 85% of seeds germinated on the fourth day, and nearly all young plants emerged from the soil on the fifth day.

3.15 Gap filling

Gap filling was done at 10 DAS by dibbling the seeds wherever the previous dibbled seeds did not germinate to achieve the required plant population in the experimental plot.

3.16 Application of post-emergence herbicide

The herbicide Irish @ 1200 ml ha^{-1}was sprayed as post-emergence at 14 DAS as per the treatment using a hand-operated knapsack sprayer fitted with a flat fan nozzle.

3.17 Intercultural operations

3.17.1 Thinning

Only one healthy seedlings were preserved per plot for appropriate development and to avoid a crowded environment. When necessary, thinning was carried out for this.

3.17.2 Weeding

Weeding was done according to par treatment requirements.

3.17.3 Plant protection measures

The crop was sprayed with Imidacloprid 17.8 SL @ 0.4 ml/liter water per the need-based requirement to save the crop from various insect and pest attacks.

3.17.4 Irrigation

Two irrigation were given. 1st irrigation was given at 25 DAS, whereas the second irrigation was given at 55 DAS.

3.18 Harvesting of main crop and other crops

Maize

Maize was grown as a green fodder crop and harvested on 19 February 2022.

Red amaranth

Red amaranth leaves are ready to harvest as soon as they are big enough to eat. It was harvested on 19 February 2022.

Soybean

At maturity, the crop was harvested manually. After complete drying of biomass, threshing was done manually, and after winnowing, clean seeds were collected separately, and their weights were recorded in kg $plot^{-1}$ along with biomass. It was harvested on 10 April 2022.

3.19 Field operation

The different field operations performed during the present investigation were given below in chronological order in list form.

Table 1. List of schedule of field operations done during experimentation

Sl. No.	Field operations	Date
1	Final land preparation	25 December 2021.
4	Layout of the experimental field	25 December 2021
3	Fertilizer application	25 December 2021
5	Sowing of seeds	26 December 2021
8	Straw mulching	26 December 2021
6	Intercropping seed sowing	26 December 2021
7	Spraying of pendimethalin EC @ 400 ml ha^{-1}	28 December 2021
10	Germination of seeds	1 January 2022
11	Gap filling	6 January 2022
12	Application of post-emergence herbicide	10 January 2022
13	Thinning	20 January 2022
14	Weeding	20 January 2022
15	Irrigation	20 January and 19 February 2022
16	Harvesting of main crop and other crops	
	Maize	19 February 2022
	Red amaranth	19 February 2022
	Soybean (Maincrop)	10 April 2022

3.20 Data collection

The data were recorded on the following parameters.

Weed data

i. Weed flora in the soybean field

ii. Weed density (m^{-2})
iii. Relative weed emergency (%)
iv. Weed dry matter weight (g m^{-2})
v. Weed control efficiency (%)
vi. Simpson's diversity index (SDI)

a) Growth parameters

vii. Plant height (cm)
viii. No. of branches $plant^{-1}$ (no.)
ix. No. of leaves $plant^{-1}$
x. SPAD value
xi. Fresh weight $plant^{-1}$
xii. Dry matter weight $plant^{-1}$ (g)
xiii. Number of nodules $plant^{-1}$ (no.)
xiv. Fresh weight of nodules $plant^{-1}$(g)
xv. Dry weight of nodules $plant^{-1}$(g)

b) Yield contributing characters

xvi. Pods $plant^{-1}$ (no.)
xvii. Pod length $plant^{-1}$ (cm)
xviii. Seeds pod^{-1} (no.)
xix. 1000-seed weight (g)

c) Yield characters

xx. Seed yield (t ha^{-1})
xxi. Stover yield (t ha^{-1})
xxii. Biological yield (t ha^{-1}) and
xxiii. Harvest index (%)

3.21 Procedure of recording data

i. Weed flora in the experimental field

Weed species found in the experimental field were recorded according to their's common name, scientific name, and family.

ii. Weed density (m^{-2})

From the pre-demarcated area of 1 m^2 of each plot, the total weeds were uprooted and counted at 60 and 90 DAS in the experimental field of soybean.

iii. Relative weed emergence

Relative weed emergence in the weedy check plot was estimated at 60 and 90 DAS. The relative weed density was worked out as per the formula given by Mishra (1968).

$$\text{Relative weed emergence (\%)} = \frac{\text{Emergence of individual weed species}}{\text{Emergence of all weed species}} \times 100$$

iv. Weed dry matter weight (g m^{-2})

After counting the fresh weeds, weeds were then oven-dried at 80 ^{0}C until a constant weight was obtained. The sample was then transferred into desiccators and allowed to cool down to room temperature, and then the final weight of the sample was taken at 60 and 90 DAS of soybean, respectively.

v. Weed control efficiency (WCE)

Weed control efficiency was measured by using the following formula given by Gautam and Mishra (1975).

$$\text{WCE} = \frac{\text{Weed dry weight in control-weed dry weight in treated plot}}{\text{Weed dry weight in control}} \times 100$$

vi. Simpson's diversity index (SDI)

Weed diversity and frequency were summarized using Simpson's Diversity Index (Simpson, 1949). SDI is used to quantify biodiversity in ecological studies.

It takes into account the number of species present, as well as the abundance of each species:

$$\text{SDI} = 1- \sum n\frac{(n-1)}{N(N-1)}$$

Where n is the total number of plants of a particular species, and N is the total number of all weed species.

viii. Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant on different days after sowing and at harvest, respectively. The mean plant height of the soybean plant was calculated and expressed in cm.

ix. No. of branches plant^{-1}

The primary branch plant^{-1} was counted from five randomly sampled plants. It was done by counting the total number of branches of all sampled plants then the average data were recorded. Data were recorded on different days after sowing and at harvest, respectively.

xi. No. of leaves plant^{-1}

The leaves of plant^{-1} were counted from five randomly sampled plants. It was done by measuring the total number of leaves of all sampled plants and then recording the average data. Data were recorded on different days after sowing and at harvest, respectively.

xii. Fresh weight plant^{-1}(g)

Five plants were collected randomly from each plot at 15, 30, 45, 60, and 75 DAS. The sample plants were cleaned and were calculated and expressed in gram (g) for recording data using electrical weight measuring balance.

xii. Dry weight plant^{-1}(g)

Five plants were collected randomly from each plot at 15, 30, 45, 60, and 75 DAS, respectively. The sample plants were oven-dried for 72 hours at 70°C, and then the dry matter content of plant^{-1} was determined. The mean dry matter plant^{-1} of the soybean plant was calculated and expressed in gram (g) for recording data.

iv. SPAD value

The SPAD value was measured by using a chlorophyll meter. Five plants per plot were selected randomly, and SPAD values at 45 and 60 DAS were recorded from the fully matured leaves counted from the top of the plants, the youngest fully expanded leaf.

iv. Number of nodules plant^{-1} (no.)

The number of nodules plant^{-1} was counted from each selected plant sample at 75 DAS.

v. Fresh weight of nodules plant^{-1} (g)

Nodules of fresh weight plant^{-1}were counted from each selected plant sample at 75 DAS. After being collected and counted, nodules were oven-dried oven maintaining 70^0C for 72 hours for oven drying until they attained a constant weight, and the mean dry weight of nodules plant^{-1} was measured.

v. Dry weight of nodules plant^{-1} (g)

Nodule plant^{-1} was counted from each selected plant sample at 75 DAS. After being collected and counted, nodules were oven-dried oven maintaining 70^0C for 72 hours for oven drying until they attained a constant weight, and the mean dry weight of nodules plant^{-1} was measured.

vii. Pods plant^{-1} (no.)

Pods plant^{-1} was counted from the five selected plant samples, and then the average pod number was calculated.

viii. Pod length plant^{-1} (cm)

Pod length is measured by the scale on five tagged plants and averaged to pod length.

ix. Number of seeds pod^{-1}

The number of seeds pod^{-1}werecounted randomly from selected pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

x. Weight of 1000-seed (g)

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance, and weight was expressed in grams (g).

xi. Seed yield (kg ha^{-1})

Seed yield was recorded from the 1 m^2 area of each plot and was sun-dried properly. The weight of seeds was taken and converted to the yield in kg ha^{-1}.

xii. Stover yield (kg ha^{-1})

After separating seeds from the plant, the straw and shell from the harvested area were sun-dried, and the weight was recorded and then converted into kg ha^{-1}.

xiii. Biological yield (kg ha^{-1})

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:
Biological yield = Seed yield + Stover yield.

xiv. Harvest index (%)

The harvest index was calculated from the seed yield and stover yield of soybean for each plot and expressed in percentage.

$$\text{Harvest index (HI \%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.22 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer program named Statistix10 Data analysis software. The mean differences were adjudged by the Least Significant Difference (LSD) test at a 5% level of probability (Lee and Lee, 2018).

CHAPTER IV

RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on soybean growth and yield as influenced by weed management treatments. The information was presented in various tables and figures. The results were discussed, and possible interpretations were provided under the headings listed below.

4.1 Weed flora in the experimental field

Weeds reduce crop yields through various mechanisms that interfere with crop growth and development. Weeds compete with crops for one or more plant development components such as mineral nutrients, water, solar energy, and space, and thus make crop cultivation processes more difficult. The experimental field was invaded with various sorts of weeds during this experiment. Seven different weed species were observed in the experimental field, with sedge, grass, and broadleaf weed species dominating (Table 2). Among the infesting different categories of weed species, two were grasses, one sedge. one herb, and three broadleaves. The weed species were belonging to the families of Labiatae, Poaceae, Boraginaceae, Asteraceae, Amaranthaceae, and Cyperaceae. The grasses were *Echinochloa colona, and Cynodon dactylon.* Herb was *Alternanthera philoxeroides.* Sedge was *Cyperus rotundus*, and the broadleaf were *Brassica kaber*, *Heliotropium indicum*, and *Enydra fluctuans.* The result obtained from the present study was similar to the findings of Chander *et al.*(2013), who reported that the field of soybean was infested with *Commelina benghalensis, E. colona, Aeschynomene indica, Ageratum conzoides, Panicum dichotomiflorum, Digitaria saniguinalis, Eleusine indica, and C. rotundus.*

Table 2. Weed flora in the soybean field during the experiment

Local name	Common name	Scientific name	Family	Type
Bon Shorisha	Wild Mustard	*Brassica kaber*	Labiatae	Broadleaf
Choto-shama	Jungle rice	*Echinochloa colona*	Poaceae	Grass
Durba	Bermuda Grass	*Cynodon dactylon*	Poaceae	Grass
Hatirshur	Indian heliotrope	*Heliotropium indicum*	Boraginaceae	Broadleaf
Helencha	Buffalo spinach	*Enydra fluctuans*	Asteraceae	Broadleaf
Maloncho	Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae	Broadleaf
Mutha	Purple Nutsedge	*Cyperus rotundus*	Cyperaceae	Sedge

4.2 Species-wise weed density and relative weeds emergence (%)

Table 3 shows species-specific weed density (m^{-2}) and relative weeds emergence (%) of weeds recorded in weedy check plots at 60 and 90 DAS. The experimental result clearly shows that sedge and grass weeds predominated in weedy check plots of the soybean field. *C. rotundus* was the most prevalent weed, with the highest weed density (128.67 and 123 m^{-2}) and relative weed emergence (38.79 and 43.16 %) in the weedy check plot at 60 and 90 DAS, followed by *E. colona* and *C. dactylon*. At the same time, the dominance of *H. indicum* and *A. philoxeroides* was lowest among all weed species in the weedy check plot at 60 and 90 DAS. The result was similar to the findings of Panda *et al.* (2015) who reported that the grassy weeds were predominant (76.28%) in an experimental field compared with broad leaves weeds (23.73%). However, *E. colona* (34%) and *Dinebra retroflexa* (25%) were predominant in soybean but other weeds like *C. rotundus* (L.), *C. dactylon* (L.), *A. philoxeroides* (L.), *Ecliptaalba* (L.) and *Mollugo pentaphylla* (L.) were also present.

Table 3. Species-wise weed density (No. m^{-2}) and relative weeds emergence (%) in weedy check plots at 60 and 90 DAS

Scientific name	Weed density (No. m^{-2})		Relative weeds emergence (%)	
	60 DAS	90 DAS	60 DAS	90 DAS
Cyperus rotundus	128.67	123	38.79	43.16
Cynodon dactylon	50.33	44.67	15.17	15.67
Brassica kaber	17.67	13.67	5.33	4.8
Heliotropium indicum	13	8	3.92	2.81
Echinochloa colona	65.33	48	19.7	16.84
Enydra fluctuans	41	35.67	12.36	12.51
Alternanthera philoxeroides	15.67	12	4.73	4.21
Total weed	331.67	285.01	100 %	100 %

4.3 Weed density m^{-2}

Weeds grow more quicker than field crops (Chander *et al.*, 2013). Weeds are taking advantage of their initial slow development to use more resources and control crops. Weeds primarily compete with crops for nutrients, solar radiation, soil moisture, and so on, increasing dry matter accumulation. Weed density was significantly affected by different weed management practices on different days after sowing. The experimental result showed that, among the various weed management practices, the T_1 (No weeding) treatment had the highest weed density (45.67 and 39.33 m^{-2}) at 60 and 90 DAS (Table 4). While the T_{12} (weed-free) treatment had the lowest weed density (0.0 and 0.0 m^{-2}) at 60 and 90 DAS. Yadav (2016) reported that weed intensity at 14, 28, 42 DAS and at harvest was significantly lower in weed-free check over the rest of the treatments. It was followed by pendimethalin @ 1 kg a.i. ha^{-1} fb. one hoeing at 30 DAS. The treatment weedy check recorded the highest weed intensity and weed dry matter as compared to other treatments. The treatment weed-free check controlled the weeds to 89.18 percent and pendimethalin @ 1 kg a.i. ha^{-1}fb.one hoeing at 30 DAS controlled the weeds to 77.52 percent over the weedy check.

4.4 Weed dry weight g m^{-2}

Weed dry weight m^{-2} was significantly affected by various weed management practices on various days after sowing (Table 4).The experimental result revealed that the T_1 (No weeding) treatment had the highest weed dry weight (36.13 and 19.87 g m^{-2}) at 60 and 90 DAS among the various integrated weed management practices. However, at 60 and 90 DAS, the T_{12} (weed-free) treatment had the lowest weed dry weight (0.0 and 0.0 g m^{-2}). According to Patil *et al.* (2017), the various integrated weed management strategies reduced weed dry matter. They improved weed control efficiency, resulting in a higher soybean yield comparable to the control treatment.

4.5 Weed control efficiency

At 60 and 90 DAS, different weed management strategies showed significant effects on weed control efficiency (Table 4). Weed control efficiency ranged from 00 to 100 % over the weedy check plot due to diverse integrated weed management techniques. The findings of the experiments demonstrated that the T_{12} (weed-free) treatment had the highest weed control efficiency (100 and 100 %) at 60 and 90 DAS. However, at 60 and 90 DAS, no weeding (T_1) resulted in the lowest weed control efficiency (0.0 and 0.0%). The differences in weed control efficiency were due to variations in weed density in the experiment plot, which used different integrated weed management strategies on different days after sowing. Weeding removes weeds from the field and thus reducing weed density and increasing weed control efficiency. Malviya *et al.* (2012) reported that all weed control treatments effectively controlled weeds compared to weedy check in maize + blackgram intercropping system. The highest weed control efficiency (WCE) was recorded under weed-free treatment (100%), followed by two-hand weeding at 20 and 40 DAS (66.2%) and pre-emergence application of alachlor @ 2.0 kg ha^{-1} + HW at 30 DAS (62.1%). Among pre-emergence herbicides, alachlor was most effective against weeds (52.8%) followed by pendimethalin (46%) and atrazine (39.9%).

Table 4. Effect of manual, chemical, cultural, and integrated weed managements on weed density, weed dry weight, and weed control efficiency at different DAS

Treatments	Weed density m^{-2} (No.)		Weed dry weight m^{-2} (g)		Weed control efficiency (%)	
	60 DAS	**90 DAS**	**60 DAS**	**90 DAS**	**60 DAS**	**90 DAS**
T_1	45.67 a	39.33 a	36.13 a	19.87 a	0.00 f	0.00 j
T_2	35.00 c	26.33 de	10.46 cd	7.630 e	71.05 bc	61.60 de
T_3	20.33 f	19.67 g	9.68 cd	6.82 e	73.21 b	65.68 d
T_4	33.00 cd	30.33 bc	10.10 cd	7.990 de	72.05 b	59.79 e
T_5	34.33 c	22.67 f	8.87 d	3.82 f	75.45 b	80.78 bc
T_6	19.33 f	24.67 ef	9.14 d	4.36 f	74.70 b	78.04 c
T_7	33.33 c	28.67 cd	12.43 c	9.350 d	65.60 c	52.94 f
T_8	12.00 g	7.00 h	8.52 d	3.23 f	76.42 b	83.74 b
T_9	40.00 b	27.00 de	30.75 b	15.19 b	14.89 de	23.55 h
T_{10}	30.67 d	32.67 b	32.35 b	18.79 a	10.46 e	5.44 i
T_{11}	28.00 e	26.67 de	29.56 b	12.01 c	18.18 d	39.56 g
T_{12}	0.00 h	0.00 i	0.00 e	0.00 g	100.00 a	100.0 a
$LSD_{(0.05)}$	2.44	2.93	2.92	1.46	5.51	4.88
CV(%)	5.22	7.29	10.48	9.53	6.00	5.32

In a column means having a similar letter(s) are statistically similar, and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.6 Simpson's Diversity Index (SDI)

The number of species present in the soybean field during the experiment and the abundance of each species were recorded to quantify biodiversity for ecological studies(Table 5). The highest SDI (1.0 and 1.0) at 60 and 90 DAS was obtained in the treatment. Conversely, the treatment had the lowest SDI (0.98 and 0.98) at 60 and 90 DAS.

Table 5. Simpson diversity index (SDI) of different weeds found in different treated plots during the field experiment

Treatments	Simpson diversity index (%)			
	60 DAS	60 DAS (%)	90 DAS	90 DAS (%)
T_1	0.98	98	0.98	98
T_2	0.98	98	0.99	99
T_3	0.99	99	0.99	99
T_4	0.99	99	0.98	98
T_5	0.98	98	0.99	99
T_6	0.99	99	0.99	99
T_7	0.99	99	0.99	99
T_8	0.99	99	0.99	99
T_9	0.98	98	0.99	99
T_{10}	0.99	99	0.98	98
T_{11}	0.99	99	0.99	99
T_{12}	1	100	1	100

Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.7 Plant growth parameters

4.7.1 Plant height (cm)

Plant height is an important morphological character that is a potential indicator of the availability of growth resources in its approach. The experiment results demonstrated that soybean plant height varied significantly due to the effect of different weed management practices (Figure 1). The highest plant height (13.19 cm) was observed in T_8 treatment at 15 DAS; at 30 DAS from T_9 treatment (20.08 cm), which was statistically similar toT_{11} (17.17 cm), T_7 (17.28 cm), T_4 (17.62 cm) and T_1 (18.07 cm) treatment; at 45 DAS from T_{11} treatment (30.97 cm) which was statistically comparable with T_9 (29.34 cm), T_7 (26.46 cm), T_4 (26.52 cm), T_3 (25.98 cm) and T_1 (26.86 cm) treatment; at 60 DAS from T_{11} treatment (42.41 cm) which was statistically comparable with T_9 (41.13 cm), T_7 (37.43 cm), T_3 (35.86 cm), T_2 (38.91 cm) and T_1 (36.58 cm) treatment; at 75 DAS from T_9 treatment (53.98 cm) and at harvest respectively from T_6 treatment (46.41 cm). While the lowest plant height (10.13 cm) was found in T_3 treatment at 15 DAS; at 30 DAS fromT_8 (16.37 cm) treatment which was statistically comparable with T_{12} (16.71 cm), T_{10} (16.72 cm), T_6 (15.97 cm), T_5 (15.94 cm) and T_2 (16.60 cm) treatment; at 45 DAS from T_5 (23.38 cm) treatment which was statistically comparable with T_{10} (24.52 cm), T_8 (25.37 cm), T_6 (25.83 cm) and T_2 (25.04 cm) treatment; at 60 DAS from T_{10} (32.09 cm) treatment which was statistically comparable with T_{12} (34.77 cm), T_8 (34.92 cm), T_5 (33.40 cm) and T_4 (35.48 cm) treatment; at 75 DAS from T_{10} (32.71 cm) treatment which was statistically comparable with T_5 (35.36 cm) treatment and at harvest respectively from T_9 (38.87 cm) treatment which was statistically comparable with T_{10} (41.68 cm), T_8 (41.29 cm), T_7 (41.40 cm), T_2 (41.70 cm) and T_1 (41.62 cm) treatment. The variation in plant height may be due to the adaptation of different weed management practices. Jadhav (2013) reported that integrated weed management treatments, i.e., quizalofopethyl 0.05 kg ha^{-1} and chlorimuron-ethyl 0.009 kg ha^{-1}as post-emergence at 15 DAS + hand weeding at 30 DAS, recorded significantly higher plant height which was at par with the weed-free check.

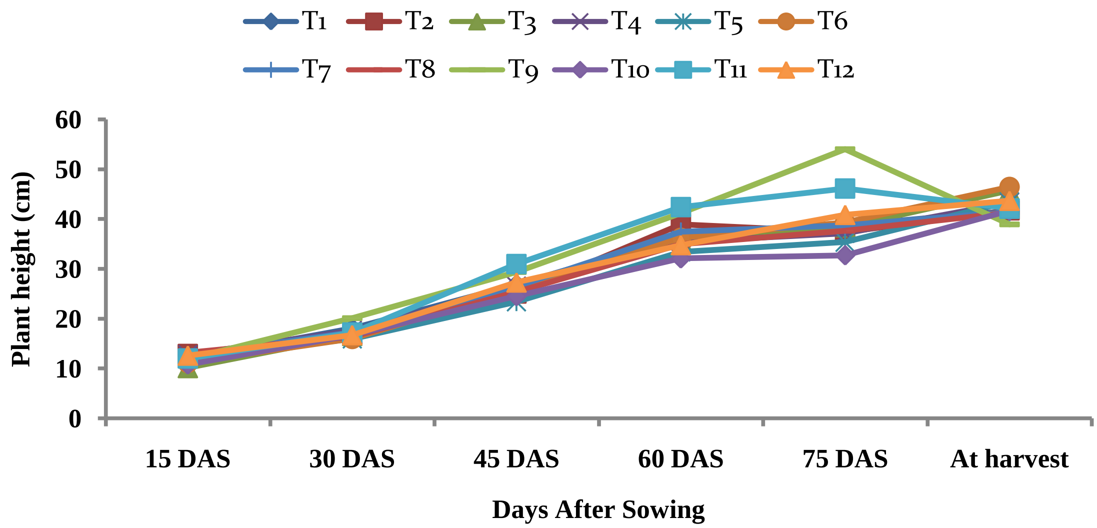


Figure 1. Effect of manual, chemical, cultural, and integrated weed managements on plant height of soybean at different DAS

Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.7.2 Leaves plant^{-1} (No.)

The number of leaves plant^{-1}of soybean on various days after sowing varied significantly, depending on the different weed management treatments (Figure 2). The experimental results revealed that at 15 DAS, T_9 (5.00) treatment had the highest number of leaves plant$^{-1,}$ which was statistically similar toT_{12} (4.22), T_{11} (4.44), T_8 (4.89), T_6 (4.33), T_5 (4.00), T_4 (4.56), T_3 (4.11), T_2 (4.78) and T_1 (4.33) treatment; at 30 DAS from T_2 (10.56) treatment which was similar with T_{12} (8.56), T_{11} (8.89), T_9 (9.33), T_8 (9.11), T_7 (8.56), T_6 (8.88), T_5 (8.67), T_4 (9.44) and T_1 (9.00) treatment; at 45 DAS from T_1 (25.00) treatment which was statistically comparable with T_{12} (23.78), T_{11} (21.11), T_9 (22.56), T_8 (20.56), T_7 (20.78), T_6 (20.89), T_5 (23.00), T_3 (22.44) and T_2 (24.56) treatment and at 75 DAS from T_6 (31.33) treatment which was statistically comparable with T_{12} (27.78), T_9 (25.78), T_8 (26.33), T_7 (28.77), T_5 (28.89), T_4 (30.78), T_2 (31.22) and T_1 (26.78) treatment. However, the lowest number of leaves plant^{-1} (3.44, 8.00, 17.22, and 21.89) at

15, 30, 45, and 75 DAS was observed in T_{10} treatment, which was statistically comparable with T_7 (3.33) treatment at 15 DAS; with T_3 (7.89) treatment at 30 DAS; with T_4 (18.11) treatment at 45 DAS and with T_{11} (22.56) treatment at 75 DAS. Different weed management practices significantly improved the number of leaves plant^{-1}, which might be due to the increased leaf number due to a reduced weed population in these treatments causing favorable soil moisture and nutrient availability which helps in rapid cell development. A similar result was observed by Koodi (2010) who reported that the highest number of leaf plant^{-1} (at 40 DAS) with two-hand weeding (20 & 40 DAS) (36.03 leaves) closely followed by imazethapyr 125 g/ha (20 DAS) (34.71 leaves) and imazethapyr 75 g/ha (20 DAS) (29.30 leaves).

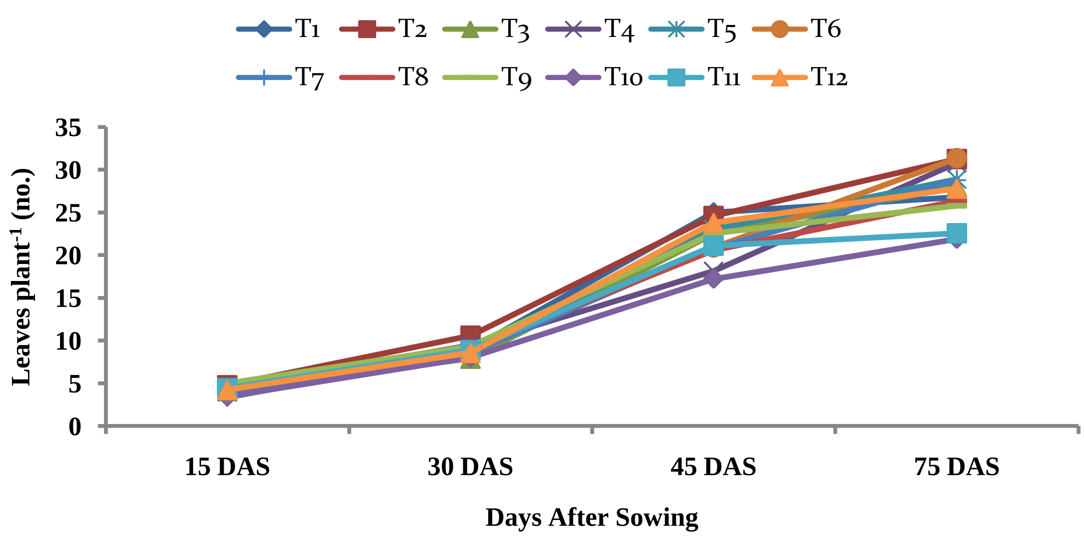


Figure 2. Effect of manual, chemical, cultural, and integrated weed managements on the number of leaves plant^{-1} of soybean at different DAS

Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.7.3 SPAD value

SPAD value determines the chlorophyll content in the leaf. In this experiment, soybean leaf SPAD value varied significantly at various days after sowing due to the effect of different weed management treatments (Figure 3). The experimental result revealed that at 45 DAS, the T_9 (44.46) treatment had the highest SPAD value, which was statistically similar toT_7 (41.58), T_6 (42.50), T_4 (42.32), T_3 (43.08), T_2 (43.75) and T_1 (39.20) treatment, however, at 60 DAS the T_3 (48.29) treatment had the highest SPAD value which was statistically similar with T_7 (45.03), T_6 (43.40), T_5 (45.19), T_3 (48.29) and T_1 (45.62) treatment. While the lowest SPAD value was found in the T_{10} (35.79) treatment at 45 DAS, which was statistically comparable with T_{11} (37.97), T_8 (38.52), and T_5 (37.94) treatment, and at 60 DAS, the lowest SPAD value was found in T_{11} (37.17) treatment which was statistically comparable with T_{12} (41.82), T_{10} (37.80), T_9 (39.51) and T_8 (41.30) treatment. Kumar *et al.* (2016) found that pre-emergence application of pendimethalin @ 1 kg ha^{-1} supplemented with post-emergence application of bispyribac-sodium @ 30 gha^{-1} at 20 DAS and hand weeding significantly reduced the grain sterility percentage and increased the leaf area index, chlorophyll content and photosynthetic rate.

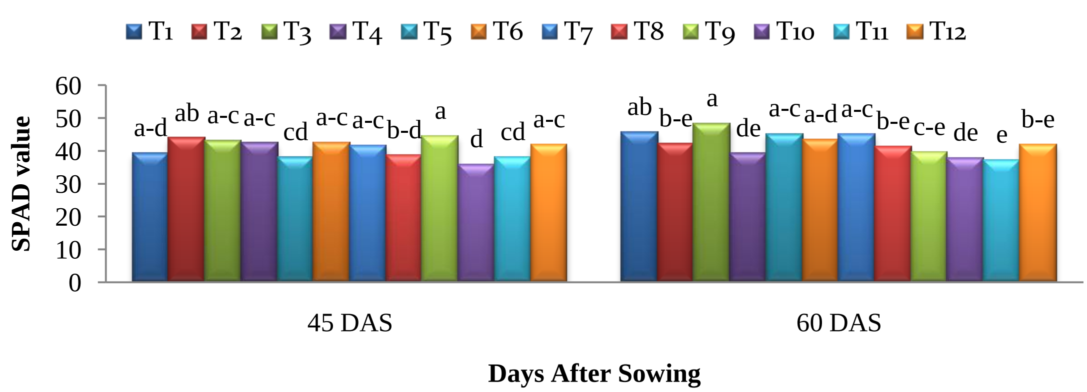


Figure 3. Effect of manual, chemical, cultural, and integrated weed managements on SPAD value of soybean at different DAS

In the bar graph, having a similar letter(s) are statistically similar, and those having a dissimilar letter(s) differ significantly at a 5% level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.7.4 Number of nodules plant^{-1}

The number of nodules on plant^{-1} of soybean was significantly changed depending on the weed management treatments (Table 6). The experimental result showed that the T_4 treatment had the highest number of nodules plant^{-1} (5.78), which was statistically comparable to all other treatments except the T_6 treatment. While the T_6 treatment had the lowest number of nodules plant^{-1} (5.78). Raghavendra *et al*. (2017) observed that the nodule number of chickpea, is generally found to vary at different crop growth stages. Among herbicides, more nodules were observed in phenaxoprop-ethyl treated plot (24 per plant), and less number of nodules (20 per plant) were noticed in oxyfluorfen treatment.).-

4.7.5 Fresh weight of nodules plant^{-1} (g)

Different weed management treatments have shown a nonsignificant effect on the fresh weight of nodules plant^{-1} of soybean (Table 6). The highest fresh weight of nodules plant^{-1} was obtained in the T_{12} treatment(1.49 g). At the same time, the T_6 treatment had the lowest fresh weight of nodules plant^{-1} (1.01 g).

4.7.6 Dry weight of nodules plant^{-1} (g)

Qin et al. (2022) reported that intercropped soybean with maize showed a higher nodule dry weight plant-1 and N_2 fixation efficiency under low P availability than mono-cropped soybean, as evidenced by improvement in the number, dry weight, and nitrogenase activity of nodules. The dry weight of nodules in plant-1soybean significantly changed depending on the weed management treatments (Table 6). The experimental result showed that the T_{10} treatment had the highest dry weight of nodules plant-1(0.42 g), which was statistically comparable to T_{12} (0.11 g), T8 (0.11 g), T7 (0.12 g), T4 (0.13 g), T1 (0.13 g), treatment. At the same time, the T6 treatment had the lowest dry weight of nodules plant-1(0.06 g), which was statistically comparable to T_{11} (0.09 g), T_9 (0.07 g), T_5 (0.10 g), T_3 (0.08 g), T_2 (0.07 g), treatment.

Table 6. Effect of manual, chemical, cultural and integrated weed managements on number of nodules plant^{-1}, freshweight of nodules plant^{-1}, dry weight of nodules plant^{-1} of soybean

Treatments	No. of nodules plant^{-1}	Fresh weight of nodules plant^{-1} (g)	Dry weight of nodules plant^{-1} (g)
T_1	5.56 ab	1.34	0.13 ab
T_2	3.89 ab	1.10	0.07 b
T_3	4.00 ab	1.10	0.08 b
T_4	5.78 a	1.39	0.13 ab
T_5	4.44 ab	1.16	0.10 b
T_6	3.33 b	1.01	0.06 b
T_7	5.22 ab	1.30	0.12 ab
T_8	4.89 ab	1.24	0.11 ab
T_9	3.78 ab	1.09	0.07 b
T_{10}	4.33 ab	1.16	0.42 a
T_{11}	4.44 ab	1.21	0.09 b
T_{12}	5.33 ab	1.49	0.11 ab
$LSD_{(0.05)}$	2.39	ns	0.31
CV(%)	30.82	24.81	146.91

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.7.7 Dry weight plant^{-1} (g)

The dry weight plant^{-1} of soybean varied significantly according to different weed management treatments at different days after sowing (Table 7). The experimental result showed that the T_2 treatment had the highest dry weight plant^{-1} (7.97, 8.43, 23.72, 14.61, and 14.85 g) at 15, 30, 45, 60, and 75 DAS which was statistically comparable with the T_8 (5.97 g) at 15 DAS; with T_{12} (6.48 g), T_{11} (6.91 g), T_9 (8.05 g), T_6 (6.76 g), T_4 (6.53

g), and T_1 (7.41 g) at 30 DAS; with T_{12} (20.06 g) and T_4 (21.35 g) at 45 DAS; with T_{12} (10.37 g), T_{11} (11.78 g), T_9 (14.01 g), T_8 (12.87 g), T_7 (12.20 g), T_6 (13.16 g), T_5 (10.81 g), T_4 (13.10 g), T_3 (11.20 g) and T_1 (13.47 g) treatment at 60 DAS and withT_{12} (12.31 g), T_{11} (12.35 g), T_9 (13.90 g), T_8 (14.04 g), T_7 (12.79 g), T_6 (12.85 g), T_5 (11.82 g), T_4 (14.34g), T_3 (12.57 g) and T_1 (13.84 g) treatment at 75 DAS. Different weed management treatments caused remarkable variations in the quantity of dry matter accumulation on different days after sowing. The variation in dry weight plant^{-1} of soybean among treatments could be attributed to less weed crop completion as a result of different weed treatments used, thereby facilitating luxurious crop growth resulting in more dry matter production per plant. The result obtained from the present study was similar to the findings of Singh *et al.* (2014), who reported that the maximum crop dry matter of mungbean was recorded under two-hand weeding, which was significantly higher than other weed management treatments.

Table 7. Effect of manual, chemical, cultural and integrated weed managements on plant dry weight of soybean at different DAS

Treatments	Dry weight $plant^{-1}$ (g)				
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
T_1	4.30 b	7.41 a-c	14.70 b-d	13.47 ab	13.84 ab
T_2	7.97 a	8.43 a	23.72 a	14.61 a	14.85 a
T_3	3.51 b	6.12 b-d	8.63 d-f	11.20 ab	12.57 ab
T_4	4.07 b	6.53 a-d	21.35 ab	13.10 ab	14.34 a
T_5	3.48 b	5.34 cd	6.64 ef	10.81 ab	11.82 ab
T_6	4.24 b	6.76 a-d	12.36 c-e	13.16 ab	12.85 ab
T_7	4.22 b	6.02 b-d	15.49 bc	12.20 ab	12.79 ab
T_8	5.97 ab	6.88 a-d	7.18 ef	12.87 ab	14.04 ab
T_9	3.86 b	8.05 ab	15.79 bc	14.01 a	13.90 ab
T_{10}	3.32 b	4.61 d	5.08 f	9.15 b	11.18 b
T_{11}	3.83 b	6.91 a-c	11.82 c-f	11.78 ab	12.35 ab
T_{12}	4.92 b	6.48 a-d	20.06 ab	10.37 ab	12.31 ab
$LSD_{(0.05)}$	2.83	2.27	6.80	4.66	3.14
CV(%)	37.38	20.25	29.63	22.55	14.20

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.2 Yield contributing characters

4.2.1 Pods plant^{-1} (No.)

The number of pods plant^{-1} of soybean was significantly influenced by different weed management treatments (Table 8). The experimental result revealed that the highest number of pods plant^{-1} of soybean (28.79) was found in treatment which was statistically similar to T_{12} (22.33), T_7 (21.56), T_6 (23.44), T_5 (22.33), T_4 (24.44), T_3 (22.00) and T_1 (22.00) treatment. However, the treatment had the lowest number of pods plant^{-1} of soybean (18.67) which was statistically comparable withT_{11} (20.33), T_{10} (21.00), and T_9 (20.22) treatment. This might be due to a reduction in weed growth and population by different weed management treatments at different stages. This ultimately lower competition by weeds with the crop for moisture and nutrients, thus increasing pods plant^{-1} of soybean. Kumar *et al.* (2019) also found similar results as the present study and reported that in the case of greengram the highest pods plant^{-1}(19.33) was recorded under two HW at 20 and 40 DAS, which was on par with manual weeding at 25 DAS (18.66).

4.2.2 Pod length (cm)

Different weed management treatments significantly affected pod length plant^{-1} of soybean (Table 8). The experimental result showed that the highest pod length plant^{-1} (4.16 cm) was observed in the T_8 treatment, which was statistically comparable to all other treatments except the T_{12}, $T_{10,}$ and T_4 treatments. On the other hand, the shortest pod length plant^{-1} (3.58 cm) found in the T_4 treatment was statistically comparable with the T_{12} (3.63 cm)and T_{10} (3.61 cm), treatments. The results revealed that weed management had a direct effect on increasing the pod length plant^{-1} of soybean. With decreasing weed population, pod length plant^{-1} increased in soybean because of higher absorption of nutrients and water from the soil. As a result, the activity of cell division increased. This favored more vegetative growth and produced more dry matter accumulations in soybean plants, thus increasing pod length plant^{-1} of soybean. A similar result was observed by Peer *et al.* (2013), who reported that all the weed control treatments significantly influenced the yield-contributing characteristics of soybean.

4.2.3 Seeds pod^{-1} (No.)

Various weed management treatments significantly influenced the number of seed pod^{-1} of soybean (Table 8). According to the results of the experiment, the T_8 treatment had the highest seeds pod^{-1} (3.89), which was statistically comparable with T_{12} (3.67), T_{11} (3.33), T_9 (3.33), T_6 (3.78), T_5 (3.33), T_3 (3.22), T_2 (3.44) and T_1 (3.33) treatment. On the other hand, the treatment had the lowest seeds pod^{-1} (3.00), which was statistically comparable with the T_7 (3.11) and T_{10} (3.11) treatments. Jadhav (2013) reported that in weed management treatments, i.e., quizalofopethyl 0.05 kg ha^{-1}and chlorimuron-ethyl 0.009 kg ha^{-1}as post-emergence at 15 DAS + hand weeding at 30 DAS, recorded significantly had higher seeds pod^{-1} which was at par with the weed-free check. Peer *et al.* (2013) reported that integrated use of herbicides and cultural management gave better seed yield and yield attributed than their application.

4.2.4 1000-seed weight (g)

The weight of 1000 soybean seeds varied significantly due to weed control methods (Table 8). The T_{12} treatment had the highest 1000-seed weight (111.00 g), which was statistically comparable to the T_7 (106.67 g) and T_4 (110.33 g) treatments. T_9 treatment, on the other hand, had the lowest 1000-seed weight (98.33 g), which was statistically equivalent to T_{11} (99.00 g) and T_{10}(103.00 g)treatments. The result was similar to the findings of Yadav *et al.* (2016). They reported that the yield contributing characteristics like the number of seeds pod^{-1}, number of pods plant^{-1}, the weight of pods plant^{-1}, 1000-seed weight, seed, and stover yield were found significantly superior in weed-free check followed by pendimethalin @ 1 kg a.i. ha^{-1}fb.one hoeing at 30 DAS.

Table 8. Effect of manual, chemical, cultural, and integrated weed managements on pods plant^{-1}, pod length, seeds pod$^{-1,}$ and 1000-seed weight of soybean

Treatments	Pods plant^{-1} (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000-seed weight (g)
T_1	22.00 ab	3.99 ab	3.33 a-c	105.00 bc
T_2	28.79 a	3.84 ab	3.44 a-c	104.00 c
T_3	22.00 ab	3.90 ab	3.22 a-c	105.00 bc
T_4	24.44 ab	3.58 b	3.00 c	110.33 a
T_5	22.33 ab	3.91 ab	3.33 a-c	104.33 c
T_6	23.44 ab	3.94 ab	3.78 ab	109.33 ab
T_7	21.56 ab	3.98 ab	3.11 bc	106.67 a-c
T_8	18.67 b	4.16 a	3.89 a	105.33 bc
T_9	20.22 b	3.98 ab	3.33 a-c	98.33 d
T_{10}	21.00 b	3.61 b	3.11 bc	103.00 cd
T_{11}	20.33 b	3.84 ab	3.33 a-c	99.00 d
T_{12}	22.33 ab	3.63 b	3.67 a-c	111.00 a
$LSD_{(0.05)}$	7.30	0.48	0.69	4.83
CV(%)	19.39	7.45	12.19	2.72

In a column means having a similar letter(s) are statistically similar, and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.3 Yield

4.3.1 Seed yield (kg ha^{-1})

Due to different weed management treatments, soybean seed yield was significantly influenced (Figure 4). The experimental result showed that the highest seed yield (1.86 t ha^{-1}) was observed in the T_{12} treatment, which was statistically similar to the T_8 (1.63 t ha^{-1}) treatment. The lowest seed yield (0.51 t ha^{-1}) was observed in the T_1 treatment (Table 21). The differences in yield among different treatments might be due to a reduction in weed growth and the population at different stages of weed management techniques which lower competition by weeds with the crop for moisture and nutrients. Suryavanshi *et al*. (2015) reported that the highest yield attributing traits and yields of sunflower were recorded in the weed-free situation, but these parameters were found statistically at par with the application of pendimethalin0.75 kg ha^{-1} (PE) + one hoeing at 30 DAS followed by hand weeding at 40 Days after sowing and application of Pendimethalin 1.0 kg ha^{-1}(PE) + Quizalofop-ethyl 37.5 g ha^{-1} at 20 DAS. Jha *et al.* (2014) reported that the weed-free check was found the best by recording soybean's highest nodulation, yield, and yield attributes.

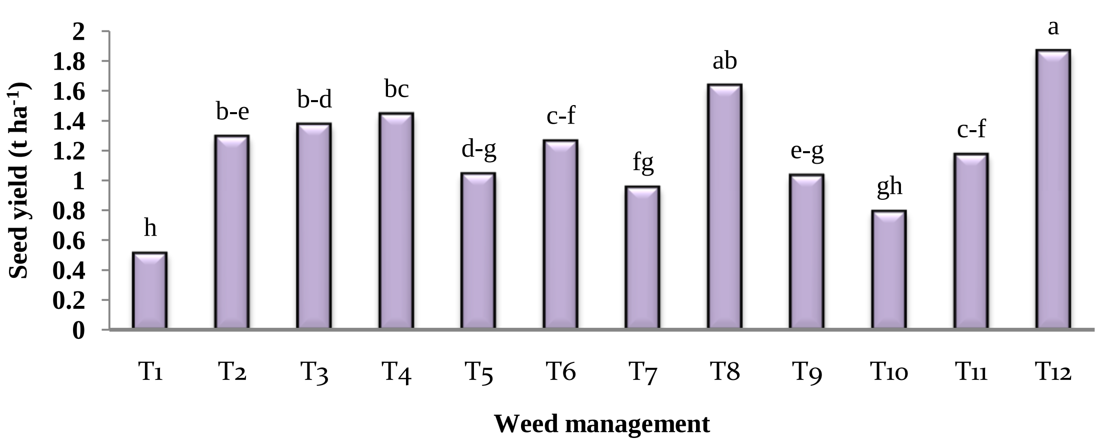


Figure 4. Effect of manual, chemical, cultural, and integrated weed management on seed yield of soybean

In the bar graph, those having similar letter(s) are statistically similar, and those having dissimilar letter(s) differ significantly at a 5% level of probability.Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.3.2 Stover yield (kg ha^{-1})

Different weed management treatments had shown a significant effect on the soybean's stover yield (Figure 5). The experiment's findings showed that the T_{12} treatment recorded the highest stover yield of soybean (2.16 t ha^{-1}), which was statistically similar toT_8 (1.93 t ha^{-1}), T_4 (2.04 t ha^{-1}), and T_3 (2.13 t ha^{-1}) treatment. On the other hand, the T_1 treatment recorded the lowest soybean stover yield (1.38 t ha^{-1}), which was statistically similar toT_{11} (1.36 t ha^{-1}), T_{10} (1.59 t ha^{-1}), T_9 (1.40 t ha^{-1}), T_7 (1.65 t ha^{-1}), T_6 (1.69 t ha^{-1}), T_6 (1.65 t ha^{-1}) and T_2 (1.62 t ha^{-1}) treatment. The stover yield differences over control treatment were due to the reason that different weed management reduced weed density which ultimate help undisturbed plant growth by utilizing its surrounding resources. Kulal *et al.* (2017)also found similar results which supported the present finding and reported that all the weed control treatments showed significantly higher stover yield of soybean over the weedy check.

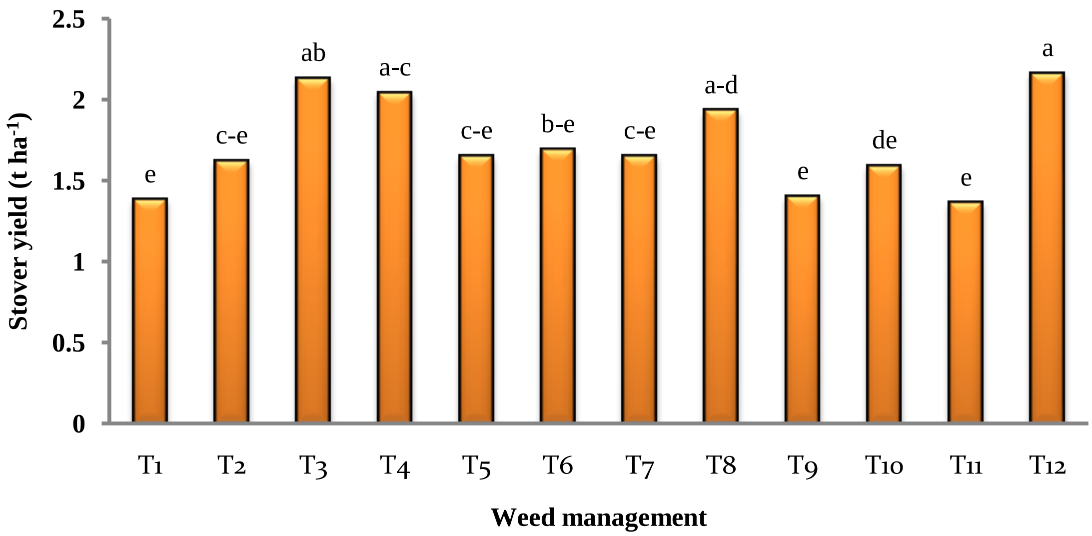


Figure 5. Effect of manual, chemical, cultural, and integrated weed management on stover yield of soybean

In the bar graph having a similar letter(s) are statistically similar, and those having a dissimilar letter(s) differ significantly at a 5% level of probability.Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.3.3 Biological yield (kg ha^{-1})

Different weed management had shown a significant effect on the biological yield of soybeans (Figure 6). The T_{12} treatment had the highest soybean biological yield (4.03 t ha^{-1}) in the experiment, which was statistically similar to the T8 (3.56 t ha^{-1}), T_4 (3.48 t ha^{-1}), and T_3 (3.49 t ha^{-1}) treatment. The T_1 treatment had the lowest soybean biological yield (1.89 t ha^{-1}) and was statistically similar to the T_{11} (2.53 t ha^{-1}), T_{10} (2.38 t ha^{-1}), and T_9 (2.43 t ha^{-1}) treatments. A significant reduction in biological yield was noticed in weedy check treatment, which might be because weeds suppressed the vegetative growth of plants by the competition between crops and weeds for soil moisture, plant nutrients, solar radiation, and space during the active growth period. Similar results were also reported by Younesabadi *et al*. (2013), who reported that all weed control treatments gave significantly higher soybean yields compared to the weedy check.

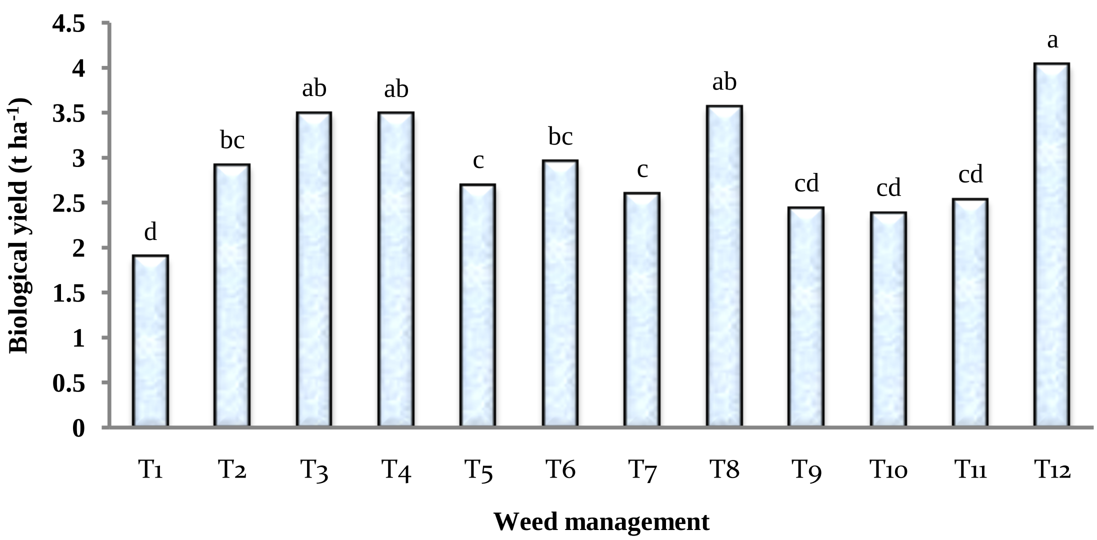


Figure 6. Effect of manual, chemical, cultural, and integrated weed management on biological yield of soybean

The bar graph having a similar letter(s) is statistically similar, and those having a dissimilar letter(s) differ significantly at a 5% level of probability.Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.3.4 Harvest index (%)

Various weed management treatments have shown significant effects on the soybean harvest index (Figure 7). The T_{12} treatment had the highest harvest index of soybean (46.35%), which was statistically similar to the T_{11} (46.27%), T_9 (42.57%), T_8 (45.57%), T_6 (42.86%), T_4 (41.61%), and T_2 (44.44%) treatments. While the T_1 treatment had the lowest soybean harvest index (26.79%), and it was statistically similar to the T_{10} (32.83%) treatment. The result obtained from the present study was similar to the findings of Mengistu and Mekonnen (2020), who reported that the highest harvest index of mungbean, 42.94%, was obtained from the weed-free check. Zaher *et al.* (2014) also reported that the harvest index was lower in the weedy check treatment.

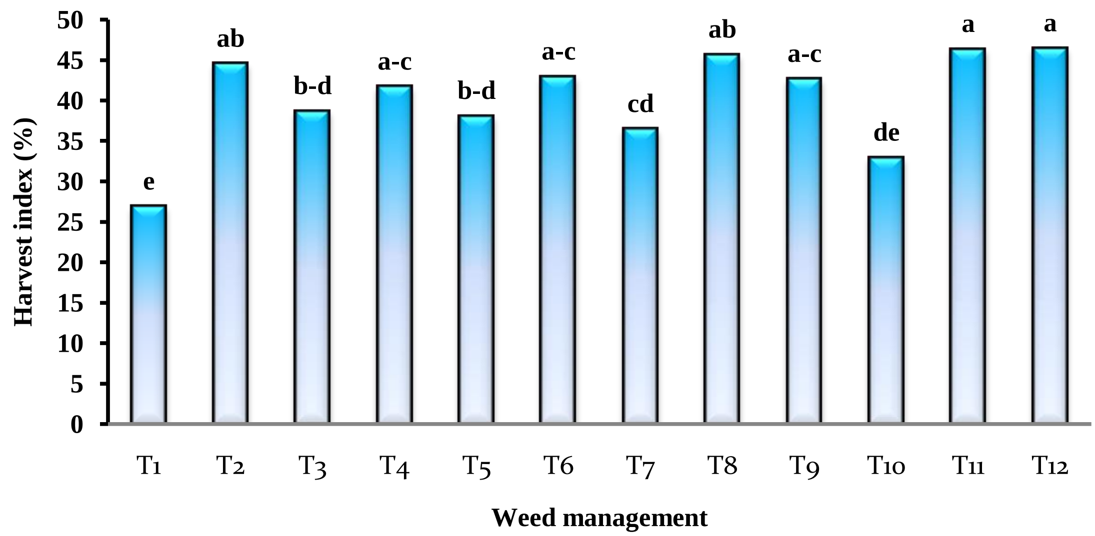


Figure 7. Effect of manual, chemical, cultural, and integrated weed management on harvest index of soybean

In the bar graph, having a similar letter(s) are statistically similar, and those having a dissimilar letter(s) differ significantly at a 5% level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

4.4 Relationship of seed yield and weed control efficiency of soybean

From (Figure 8), it was found that seed yield was positively correlated with weed control efficiency at 60 DAS (R^2=0.6301) and 90 DAS (R^2=0.7129). From the regression analysis of seed yield and weed control efficiency, it appears that soybean seed yield increased with increasing weed control efficiency. And in this experiment, maximum seed yield and weed control efficiency were recorded under weed-free treatment (T_{12}).

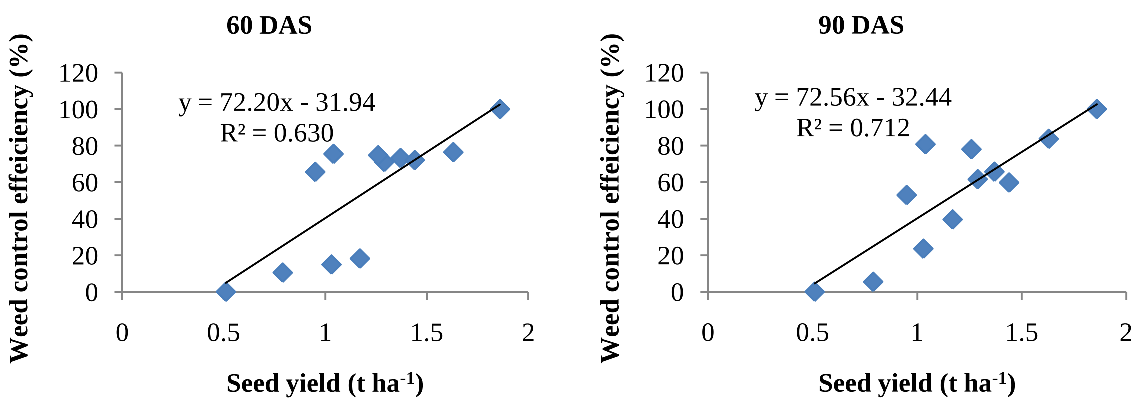


Figure 8. Relationship between seed yield and weed control efficiency of soybean at different DAS

4.5 Economic viability of different treatments combination

The economic performance of different treatments combination was determined on a per hectare area basis, which includes the total cost of production, gross returns, net returns, and benefit-cost ratio (profit over per taka investment) under treatments imposed (Table 9).

4.5.1 Total cost of production

The cost of production varied due to different weed management applied to soybean cultivation. The cost of production varied mainly for hand weeding and herbicide treatment. In the case of a weedy check, there was no involvement of cost for weed management. In this experiment highest total cost of production (81348 Tk.) was required in T_2 (Weed-free), treatment, and lowest in weed check field or control treatment.

4.5.2 Gross return (Tk)

Different weed management treatments influenced gross return. The highest gross return (188160Tk.) was recorded in T_{12} (Weed free) treatment while the minimum (52380 Tk.) in no weeding (Control) treatment (T_1).

4.5.3 Net return (Tk)

The net was varied due to different weed management treatments. The highest net return (106812 Tk.) was recorded in T_{12} (Weed free) treatment, while the minimum (4630 Tk.) net return was in no weeding (Control) treatment (T_1).

4.12.4 Benefit-cost ratio (BCR)

The benefit-cost ratio varied in different management treatments. The highest benefit-cost ratio (2.85) was obtained under $T_{4,}$ i.e., post-emergence herbicide (Irish @ 1200 ml ha^{-1})) treatment, following that T_3 (2.78), i.e., pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}) while the lowest benefit-cost ratio (1.09) was obtained in no weeding (Control) treatment (T_1). Although the weed-free treatment gave the highest return, the BCR analysis shows a comparatively lower BCR than many other treatments.

Table 9. Gross return, cost of production, net return, and benefit-cost ratio (BCR) of soybean under different weed managements

Treatment	Gross return (Tk ha^{-1})	Total cost of production (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR
T_1	52380	47750	4630	1.10
T_2	130620	65550	65070	1.99
T_3	139130	49975	89155	2.78
T_4	146040	51310	94730	2.85
T_5	105650	53535	52115	1.97
T_6	127690	58875	68815	2.17
T_7	96650	60210	36440	1.61
T_8	164930	62435	102495	2.64
T_9	104400	52712	51688	1.98
T_{10}	80590	52200	28390	1.54
T_{11}	118360	54425	63935	2.17
T_{12}	188160	81348	106812	2.31

Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka the period from December 2021 to April 2022, during the Rabi season, to study the manual, chemical, cultural, and integrated weed managements in soybean. The experiment was laid out in randomized complete block design (RCBD) with twelve weed management treatments such as T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre (Herbilin 33% EC @ 400 ml ha^{-1}) + Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_6: Pre-emergence (Herbilin 33% EC @ 400 ml ha^{-1}) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free. For the purpose of evaluating the experiment's outcomes, data on various parameters were evaluated.

The experimental result revealed that seven different weed species infested the experimental plots belonging to six families, where the most dominating were grass, sedge, and broadleaf weed species. Among different weeds, *Cyperus rotundus* was the most prevalent weed, with the highest weed density (128.67 and 123 m^{-2}) and relative weed emergence (38.79 and 43.16 %) in the weedy check plot at 60 and 90 DAS, followed by *Echinochloa colona* and *Cynodon dactylon*. At the same time, the dominance of *Heliotropium indicum* and *Alternanthera philoxeroides* was lowest among all weed species in the weedy check plot at 60 and 90 DAS.

Different weed management strategies have shown significant effects on weeds and had an impact on crop growth, yield, and yield-contributing characteristics of soybean. Among different weed management treatments, the T_8 treatment had the highest pod length (4.16 cm) and seeds pod^{-1} (3.89), while the T_{12} treatment had the highest 1000 seed weight (111.00 g). In the case of different weed management, the seed yield ranges between (0.51 -1.86 t ha^{-1}) comparable to control treatment. The highest seed yield (1.86t ha^{-1}), stover yield (2.16 t ha^{-1}), biological yield (4.03t ha^{-1}), and harvest index (46.35 %) were recorded in T_{12} (Weed free) treatment. A strong positive (R^2=0.6301) and R^2 = 0.7129, 60 and 90 DAS, respectively) a linear relationship was observed between the seed yield and weed control efficiency, where it appears that soybean seed yield increased with increasing weed control efficiency. Although the highest gross return (188160 Tk.), and net return (106812 Tk.) were obtained from weed-free treatment, the application of post-emergence herbicide (Irish @ 1200 ml ha^{-1}) was the most economically viable treatment as it gave the highest benefit-cost ratio(2.85) in soybean.

Therefore, based on the above results of the present experiment it was observed that *Cyperus rotundus* was the most prevalent weed, with the highest weed density and relative weed emergence in the weedy check plot. However, applying different weed management strategies had significant effects on weeds and impacted crop growth, yield, and yield-contributing characteristics of soybean. Although weed-free treatments gave the highest growth, yield parameters and yield, total gross return, and net return, the application of post-emergence herbicide (Irish @ 1200 ml ha^{-1}) was the most economically viable treatment as it gave the highest benefit-cost ratio in soybean cultivation which also influence the growth and increase its ability to enhance better yield production. However, further investigation is necessary for different varieties and doses of post-emergence herbicide (Irish) for higher soybean productivity under different agro-climatic conditions in Bangladesh.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from December 2021 to April, 2022

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2021	December	28.8°C	19.1°C	47%	00 mm
2022	January	25.5°C	13.1°C	41%	00 mm
	February	25.9°C	14°C	34%	7.7 mm
	March	31.9°C	20.1°C	38%	71 mm
	April	34.1°C	23.6°C	67%	138 mm

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data of weed density (m^{-2}) and weeddry weight ($g\ m^{-2}$) at 60 and 90 DAS

Mean square of					
Source		Weed density at		Weed dry weight at	
	df	60DAS	90 DAS	60 DAS	90 DAS
Replication (R)	2	2.083	3.000	4.083	0.750
Treatment (T)	11	484.981*	348.773*	436.097*	117.739*
Error	22	2.083	3.000	2.992	0.750

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of weed control efficiency (%) at 60 and 90 DAS

Mean square of			
Source		Weed control efficiency at	
	df	60 DAS	90 DAS
Replication (R)	2	33.33	8.33
Treatment (T)	11	3341.02*	2981.83*
Error	22	10.61	8.33

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of plant height of soybean at different DAS

Source	df	Mean square of plant height at					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication (R)	2	0.00376	1.52929	0.9644	8.4805	209.748	13.2723
Treatment (T)	11	2.552*	3.837*	12.687*	27.028*	550.29*	12.703*
Error	22	0.02200	3.20313	8.7945	15.5518	404.132	6.5534

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of no. of leaves plant^{-1}of soybean at different DAS

Source	df	Mean square of no. of leaves plant^{-1} at			
		15 DAS	30 DAS	45 DAS	75 DAS
Replication (R)	2	0.42901	4.68827	31.6944	22.7068
Treatment (T)	11	0.80443*	1.47363*	17.0236*	28.3533*
Error	22	0.42901	1.94416	15.0311	18.0166

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of SPAD valueof soybean at different DAS

Source	df	Mean square of SPAD value at	
		45 DAS	60 DAS
Replication (R)	2	0.2669	38.8411
Treatment (T)	11	22.6802*	35.4550*
Error	22	10.1722	11.4056

Appendix IX. Analysis of variance of the data of nodule number, nodules fresh weight plant^{-1}and nodule dry weight plant^{-1}of soybean

Source	df	Mean square of		
		No. of nodules plant^{-1}	Nodules fresh weight plant^{-1}	Nodules dry weight plant^{-1}
Replication (R)	2	0.56481	0.00748	0.02404
Treatment (T)	11	1.79209*	0.05893^{Ns}	0.02697*
Error	22	1.99579	0.09101	0.03357

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of dry weight plant^{-1}of soybean at different DAS

Source	df	Mean square ofdry weight plant^{-1} at				
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication (R)	2	10.3767	55.1276	16.471	510.028	40.8199
Treatment (T)	11	5.1826*	3.3922*	110.561*	93.907*	7.8001*
Error	22	2.7980	1.8019	16.162	73.573	7.6050

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data of number of pods plant^{-1}, pod length seeds pod^{-1} and 1000-seed weight of soybean

Source	df	Mean square of			
		Pods plant^{-1}	Pod length	Seed pod^{-1}	1000-seed weight
Replication (R)	2	5.9383	0.01059	0.02160	7.1944
Treatment (T)	11	19.5443*	0.09107*	0.22531*	46.8687*
Error	22	18.6285	0.08277	0.16975	8.1641

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix XII. Analysis of variance of the data of number of seed yield, stover yield, biological yield and harvest index of soybean

Source	df	Mean square of			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	0.24550	0.06312	0.51081	71.230
Treatment (T)	11	0.40452*	0.24442*	1.14240*	107.048*
Error	22	0.03980	0.06944	0.15178	20.219

Ns: Non significant
*: Significant at 0.05 level of probability

Appendix XIII. Wages and price of different items used in the experiment

A. Non material cost

Items	No. of labor required	Amount taka
Seed sowing	10	4000
Tractor operation	1	400
Harvesting and others works	20	8000
	Grand total= 12400	

(Individual labor wages 400 taka day^{-1}).

B. Material cost

Sl. No.	Quantity (kg/ha)/times	Items Cost (Tk)	Cost (Tk/ha)
Seed rate ha^{-1}	30	100	3000
Fertilizers			
Urea	50	16	800
TSP	150	22	3300
MP	100	15	1500
Gypsum	80	8	640
Boron	10	4.6	46
Irrigation	2 times	2000	4000
Tractor	1	3000	3000
Pesticide	2	1500	3000
(Excluding weed managements)			Grand total= 19286

Overhead cost : Land value ha^{-1} was 200000 taka. Land cost at 12.5 % interest for 6 month was 12500 taka.

Miscellaneous cost (common cost) : It was 5% of total input cost

Cost of different weed managements according with par treatment requirement.

Treatments	No weeding	Two hand weeding	Pre-emergence herbicide	Post-emergence herbicide	Pre + Post-emergence herbicide	Pre-emergence + 1 hand weeding	Post-emergence + 1 hand weeding	Pre + Post-emergence + 1 hand weeding	Straw mulching	Intercrop with red amaranth	Intercrop with maize	Weed-free	Total cost for weed management
T_1	0	0	0	0	0	0	0	0	0	0	0	0	0
T_2	0	16000	0	0	0	0	0	0	0	0	0	0	16000
T_3	0	0	2000	0	0	0	0	0	0	0	0	0	2000
T_4	0	0	0	3200	0	0	0	0	0	0	0	0	3200
T_5	0	0	0	0	5200	0	0	0	0	0	0	0	5200
T_6	0	0	0	0	0	10000	0	0	0	0	0	0	10000
T_7	0	0	0	0	0	0	11200	0	0	0	0	0	11200
T_8	0	0	0	0	0	0	0	13200	0	0	0	0	13200
T_9	0	0	0	0	0	0	0	0	4460	0	0	0	4460
T_{10}	0	0	0	0	0	0	0	0	0	4000	0	0	4000
T_{11}	0	0	0	0	0	0	0	0	0	0	6000	0	6000
T_{12}	0	0	0	0	0	0	0	0	0	0	0	32000	32000

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

Note: 1 hand weeding required 30 labour.

Appendix XIV. Total cost of production of soybean cultivations

Total cost of production

Treatments	Non-material cost (i)	Material cost (ii. a)	Weed managements cost (ii. b)	Total input cost (A = i+ ii) Here, ii= a+b	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (D)	Total cost of production (A+B+C+D)
T_1	12400	19286	0	31686	1980	1584	12500	47750
T_2	12400	19286	16000	47686	2980	2384	12500	65550
T_3	12400	19286	2000	33686	2105	1684	12500	49975
T_4	12400	19286	3200	34886	2180	1744	12500	51310
T_5	12400	19286	5200	36886	2305	1844	12500	53535
T_6	12400	19286	10000	41686	2605	2084	12500	58875
T_7	12400	19286	11200	42886	2680	2144	12500	60210
T_8	12400	19286	13200	44886	2805	2244	12500	62435
T_9	12400	19286	4460	36146	2259	1807	12500	52712
T_{10}	12400	19286	4000	35686	2230	1784	12500	52200
T_{11}	12400	19286	6000	37686	2355	1884	12500	54425
T_{12}	12400	19286	32000	45686	2878	2284	12500	81348

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence(name) + 1 hand weeding (40 DAS), T_7: Post-emergence(name) + 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

Appendix XV. Gross return from soybean cultivation

Gross return from soybean cultivation

Soybean seed = 1 kg 100 taka so 1 ton = 100000 taka

Straw value= 1 kg 1 taka so 1 ton = 1000 taka

Treatment	Seed yield (t/ha)	Value	Stover yield (t/ha)	Value	Gross retrun (Tk)
T_1	0.51	51000	1.38	1380	52380
T_2	1.29	129000	1.62	1620	130620
T_3	1.37	137000	2.13	2130	139130
T_4	1.44	144000	2.04	2040	146040
T_5	1.04	104000	1.65	1650	105650
T_6	1.26	126000	1.69	1690	127690
T_7	0.95	95000	1.65	1650	96650
T_8	1.63	163000	1.93	1930	164930
T_9	1.03	103000	1.4	1400	104400
T_{10}	0.79	79000	1.59	1590	80590
T_{11}	1.17	117000	1.36	1360	118360
T_{12}	1.86	186000	2.16	2160	188160

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T_1: No weeding (Control), T_2: Two hand weeding (15 and 30 DAS), T_3: Pre-emergence herbicide (Herbilin 33% EC @ 400 ml ha^{-1}), T_4: Post-emergence herbicide, (Irish @ 1200 ml ha^{-1}), T_5: Pre + Post-emergence herbicide, (name), T_6: Pre-emergence + 1 hand weeding (40 DAS), T_7: Post-emergence+ 1 hand weeding (40 DAS, T_8: Pre + Post-emergence + 1 hand weeding(40 DAS), T_9: Straw mulching, T_{10}: Intercrop with red amaranth, T_{11}: Intercrop with maize and T_{12}: Weed-free.

PLATES

Plate 1. Seed sowing

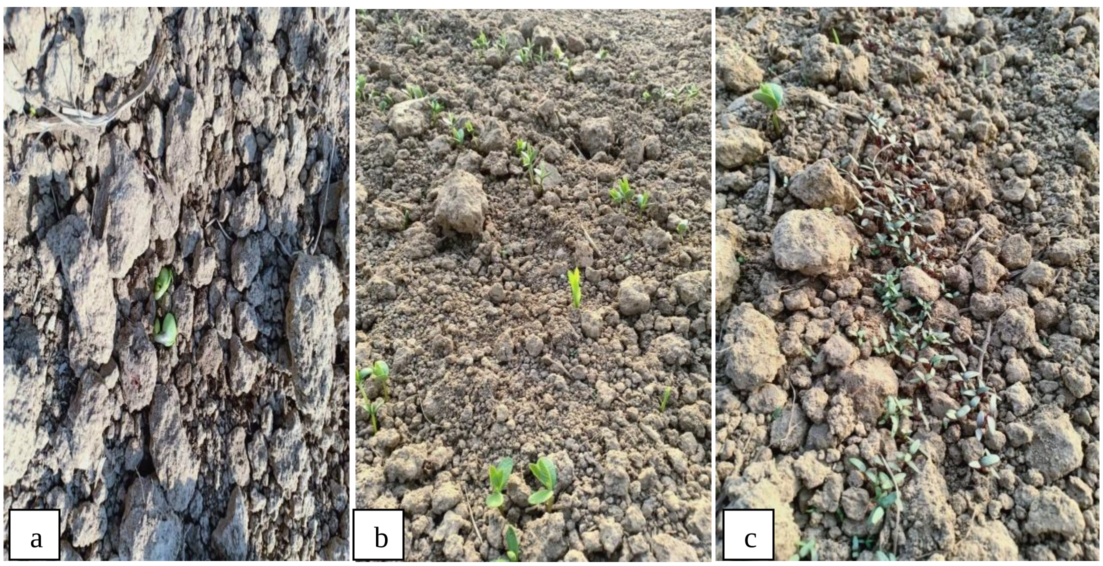

Plate 2. Germination of a. soybean, b. maize and c. red amaranth

Plate 3. Field condition after germination of seed

Plate 4. Application of irrigation and top dressing of urea

Plate 5. Collection of data using SPAD

Plate 6. Weeds present in the experimental plot

Plate 7. Field condition of at 40 DAS of soybean plants

Plate 8. Weed suppressing by straw mulching

Plate 9. Growing of maize as fodder crop by intercropping with soybean

Plate 10. Growing of maize as fodder crop by intercropping with soybean

Plate 11. Pod appearance of soybean

Plate 12. Harvesting of red amaranth, maize from soybean field


Plate 13. Field inspection by different organizations

Plate 14. Field condition before harvest

Plate 15. Data collection before harvest