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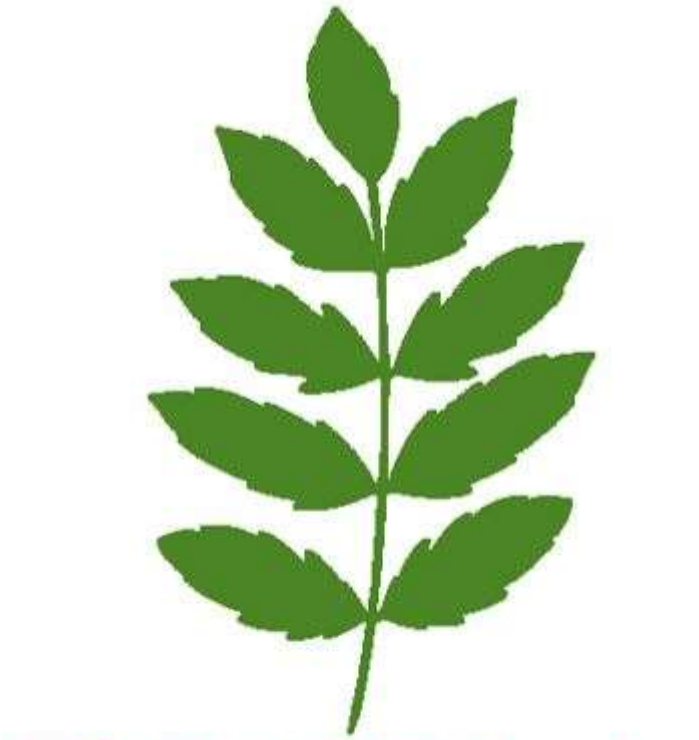

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Effect of some soil and water management practices on soil profile moisture under rain-fed conditions in Hamelmalo Region, Eritrea

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Abstract

The irregular and torrential nature of rainfall in Eritrea necessitate improving the water storage capacity and its distribution in the soil profile to sustain livelihood of rural household; hence a field experiment was conducted in the watershed area of Hamelmalo Agricultural College during the cropping season of 2018, to study the effect of tillage, farm yard manure (FYM) and mulch on water retention capacity and its distribution in the soil profile under rainfed conditions with sorghum as test crop. A split-split plot experimental design was chosen with tillage (conventional tillage CT, reduced tillage RT and no-till NT)) as the main plot, FYM (0, 5, 10, 15 t ha^{-1}) as sub-plot and mulch (0, 4 t ha^{-1}) as sub-sub-plot with three replications. Each sub-sub-plot was 15 m^2. The plots were well bunded to avoid any run-off or run-in. The distance between sub-plots and sub-sub-plots was 40 cm. The results showed that the soil moisture profile storage was affected by different soil management practices; mulch showed considerable effects on soil profile moisture content; tillage caused the reduction in moisture in the upper layers; reduced tillage with 15 t ha^{-1} FYM performed better than all other treatments in soil profile water storage and its distribution.

Keywords: Farmyard manure, Moisture content, Moisture distribution, Mulch, Soil profile, Soil profile, Tillage.

Introduction

Rainfall in Eritrea is torrential, of high intensity, short duration, and varies greatly from year to year. Average precipitation in the country is about 384 mm yr^{-1} (MoA, 2002) with only 1% of the total area receiving more than 650 mm of annual rainfall (FAO, 1994). The rationale is to conserve this water in the soil profile to eliminate soil water deficit during naturally occurring dry spells using soil and water management techniques. Although, various types of soil and water management techniques have been implemented in Eritrea for the last decades; these are not effectively put into practice or utilized due to a host of factors (Tesfay *et al.*, 2020). Rainfall that the country receives if conserved and managed properly can be enough to meet the national water need but most of it is lost through runoff, evaporation, and drainage. Hoogmoed and Stroosnijder (1984) reported that runoff losses from a field with bare soil can amount to 30-35% of storm rainfall. To reduce runoff, and thereby increase available soil water; the infiltration rate and water-holding capacity of soil have to be increased through management practices such as minimum tillage, mulching, and application of farmyard manure. If the technology is adapted by rural households, it would be possible to produce enough food for them with surplus for sale to compensate for their household demands. Bissrat *et al.*, (2012) suggested that policy makers should introduce sustainable land management practices, including efficient water harvesting and water management

strategies to cope with water scarcity and high runoff.

In view of the above background, production in arid and semi-arid areas of Eritrea could be ameliorated through effective soil and rainwater management practices. Therefore, the present study was intended to study the effect of tillage, FYM, and mulch as an effort to solve one of the major constraints i.e. available soil water to sustain the agricultural production in the country.

Materials and methods

The field experiment was conducted in Hamelmalo Agricultural College, Eritrea at 15°52'21" N and 38°27'42" E latitude and longitude, respectively and an elevation of 1285 m above mean sea level under rain-fed conditions during the summer season of 2018; annual rainfall in the growing season was 477 mm (Table 1).

Table 1: Distribution of rainfall in Hamelmalo (Eritrea) during the months of 2018

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ran-fall (mm)	0	0	0	6.6	58.5	27.8	227	135	87.3	0	7.4	0

A soil split with dimensions 1.5 m by 1.5 m was dug to a depth of 2.0 m in the center of the research plot to examine the soil profile and describe the morphological properties of the soil. FAO (1990) guidelines were used to determine the soil structure, stickiness, and plasticity. Bulk density was measured before sowing and after harvest using the core sampler Method (Blake and Hartge 1986).

Soil profile moisture per representative plot was recorded after sowing (0–100 cm) at 10 days intervals during the crop growing period to study the distribution and redistribution of soil water in the profile. A soil moisture meter (Delta-T, 2017) was used to measure the soil moisture profile with a probe from the installed access tube, inserted at 0 -110 cm depth in the soil profile.

Gravimetric water from the saturated plot was allowed to drain out and surface water content was measured gravimetrically every day till it became constant, this was attained in two days, and this constant value of water content was taken as field capacity.

Tillage - Conventional tillage (CT), reduced tillage (RT), and no-till (NT).
Farmyard manure (t ha^{-1}); F0 = 0, F1=5, F2 = 10, and F3 = 15
Mulch (t ha^{-1}); M0 = 0, M1 = 4

Split-split plot design was used with three replications. Each replication consisted of 24 plots. Tillage was taken as the main plot, FYM as the sub-plot, and mulch as the sub-sub-plot. Sorghum variety [ICSV 210 (Bushika)] was sown at a seed rate of 15 kg ha^{-1}.

The data obtained from all the measured parameters of the experiment under various treatments were subjected to statistical analysis using the GENSTAT software (12^{th}ed) and the treatment means were compared with Least Significant Difference (LSD) at a 5 per cent level of probability.

Results and discussions

Soil profile characteristics were studied to examine any kind of hindrances to restrict moisture movement through the profile. The soil of the study area is dominantly alluvial deposits from the surrounding hilly terrains. Six distinct layers/horizons with little difference were identified in the profile pit. The important profile characteristics are summarized in Table 2. The soil structure in the surface layers was granular but harder in consistency and blocky in the lower layers. The bulk density of the 0-20 cm was 1.43 Mgm^{-3} and 1.74 Mgm^{-3} in the lower layer. The increase in density might be due to lower organic matter content, low aggregation, and overload of the upper layers. The groundwater table in the area ranged from about 7m during the rainy season up to 9 m in the dry season.

Table 2: Soil profile characteristics of the study area

Layer	Depth cm	Bulk density Mg m^{-3}	Color		Texture	Structure	Consistency		Hardpan	Crop Root
			Dry	Moist			Dry	Moist		
A1	0-20	1.43	5YR 4/6 Brown	5YR 4/4 Dull Reddish Brown	Sandy Loam	Granular	Hard	Loose	None	Common
A2	20-50	1.39	5YR 5/6 Light Brown	5YR 3/2 Dark Reddish Brown	Sandy Loam	Granular	Hard	Loose	None	Common
A3	50-80	1.4	5YR 4/4 Brown	5YR 2/3 Very Dark Reddish Brown	Sandy Loam	Blocky	Loose	Loose	None	Common
A4	80-115	1.64	5YR 3/6 Dark Red	5YR 2/3 Very Dark Reddish Brown	Sandy Loam	Blocky	Loose	Loose	None	Few
A5	110-125	1.66	5YR 5/3 Dull Reddish	5YR 3/3 Dark Reddish Brown	Sandy Loam	Blocky	Loose	Hard	None	Few
A6	>125	1.74	5YR 4/3 Dull Reddish Brown	5YR ¾ Dark Reddish Brown	Sandy Loam	Blocky	Hard	Hard	None	Very Few

Soil profile moisture content was measured at depths 10 cm, 20 cm, 30 cm, 40 cm, 60 cm, and 100 cm, during the various phonological phases from sowing up to harvest (Figures 1-6). The moisture data were recorded after every ten-day interval, except the last reading which was taken after 26 days from the previous record.The results showed that the soil moisture profile storage was affected by different soil management practices. Out of the factors, mulch showed considerable

effects on soil profile moisture content (Figures 1-6). Within the factors reduced tillage with 15 t ha^{-1} FYM (RTF3M1) increased soil water storage. Hence, the availability of soil moisture in every mulched plot with 10 and 15 t ha^{-1} dose of FYM was at an optimum level, as a result statistically significant yield of sorghum was recorded in mulched plots than non-mulched. In contrast to mulch and FYM, soil tillage decreased moisture content at a depth of 10-20 cm, which might be due to increased evaporation, especially in the control non-mulched plots. However, in the control and non-mulched treatments (plots) without FYM, during the flowering stage, the crop experienced moisture stress. Similar results were reported by Sahindomi, (2003); he reported that the application of straw mulches and soil tillage can maintain the availability of soil moisture at a depth of 20 to 60 cm.

Figure 1: The average distribution of soil profile moisture content in NO TILL without mulch

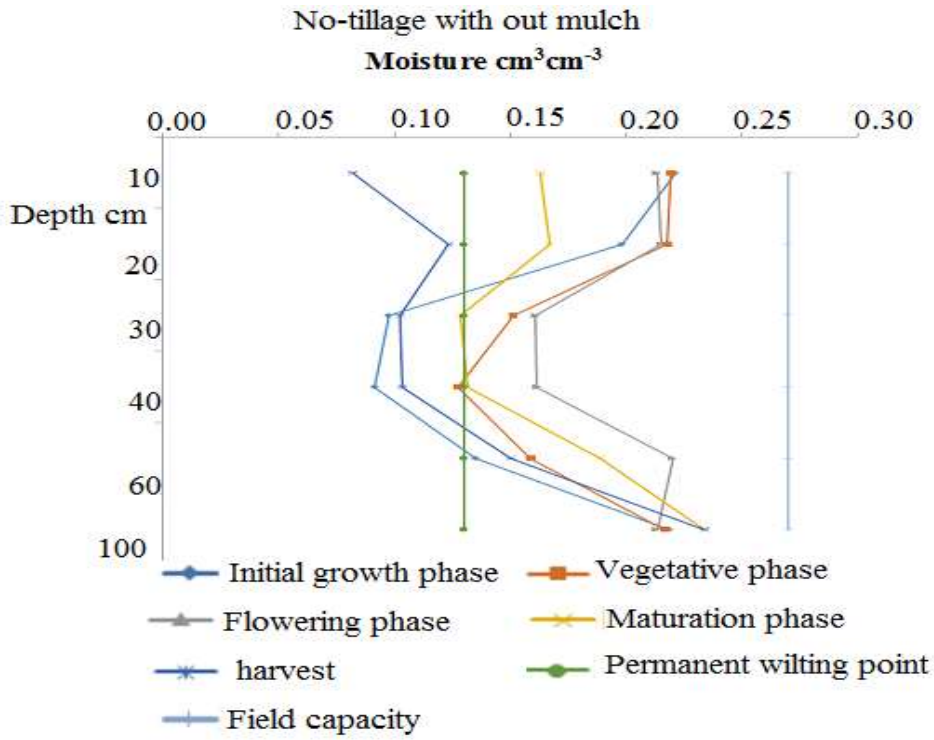


Figure 2 represented the seasonal moisture distribution in the soil profile with no tillage practices with mulch. In the mulched plots, the moisture level remained above FC up to 30 cm depth during the whole growing season; whereas in the case of non-mulched plots (Figure 2), the soil moisture was near the permanent wilting point. Hence, mulch helped to conserve soil moisture in the root zone. A review of tillage studies in Nigeria (Opara, 1990) showed that NT with residue mulch was appropriate for Luvisols.

Fig 2: The average distribution of soil profile moisture content in NO TILL with mulch

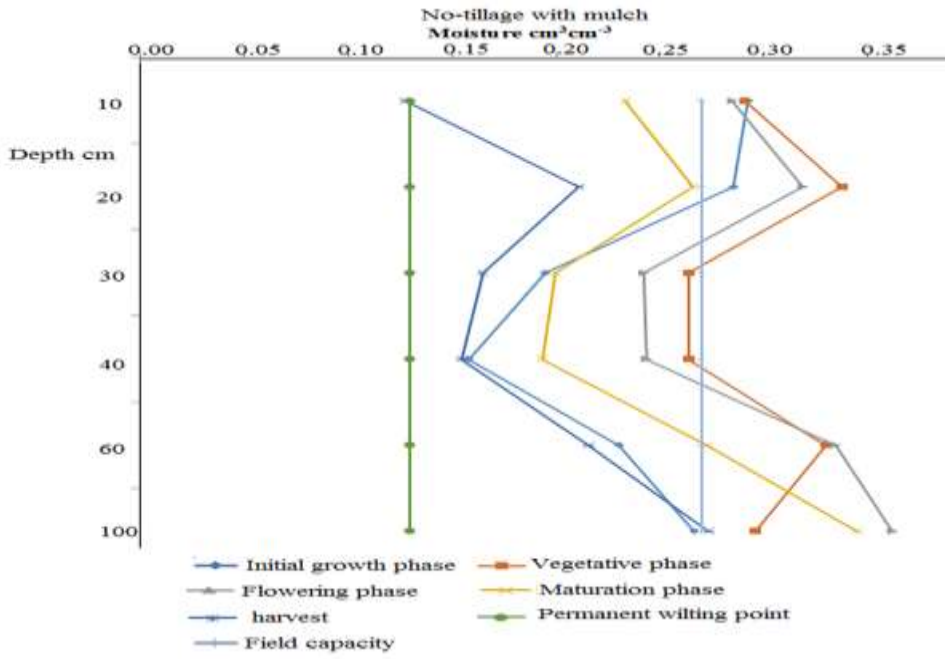
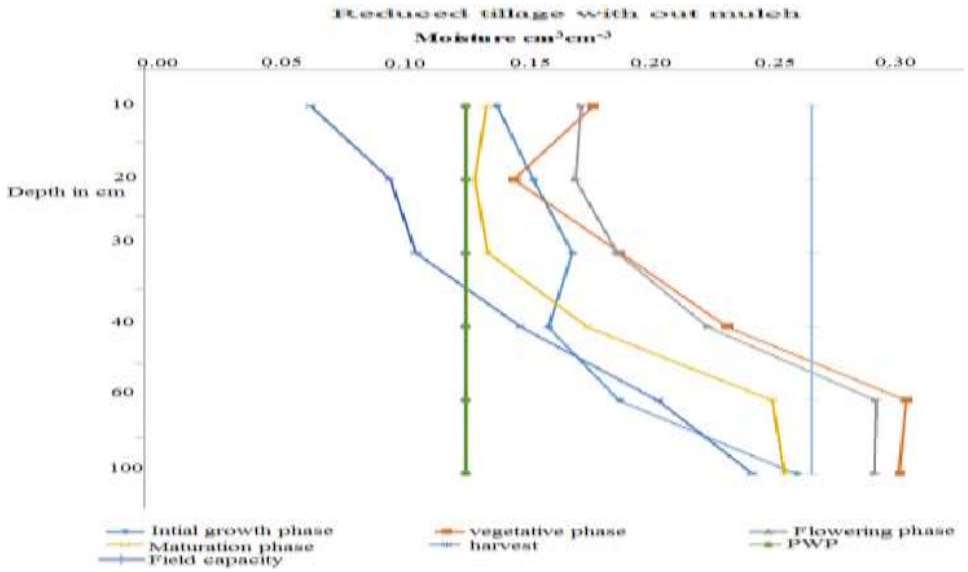


Fig 3: The average distribution of soil profile moisture content in reduced tillage without mulch



Figures 3 and 4 represented the seasonal moisture distribution in the soil profile of the reduced tillage practices without and with mulch. In non-mulched plots, soil moisture remained near permanent wilting points up to 30 cm depth. In mulched plots, it was near FC but less than the similar plots in NT, this decrease might be due to increased evaporation loss in non-mulched plots and also due to increased infiltration into down layers due to tillage in both cases; mulched plots performed better in conserving soil moisture as moisture content remained near field capacity in these plots. Zhang, (2015) also reported that in dry land farming conditions, straw mulch decreased the rate of evaporation which allowed more soil water to be accumulated as compared with untreated control.

Fig 4: The average distribution of soil profile moisture content in reduced tillage with mulch

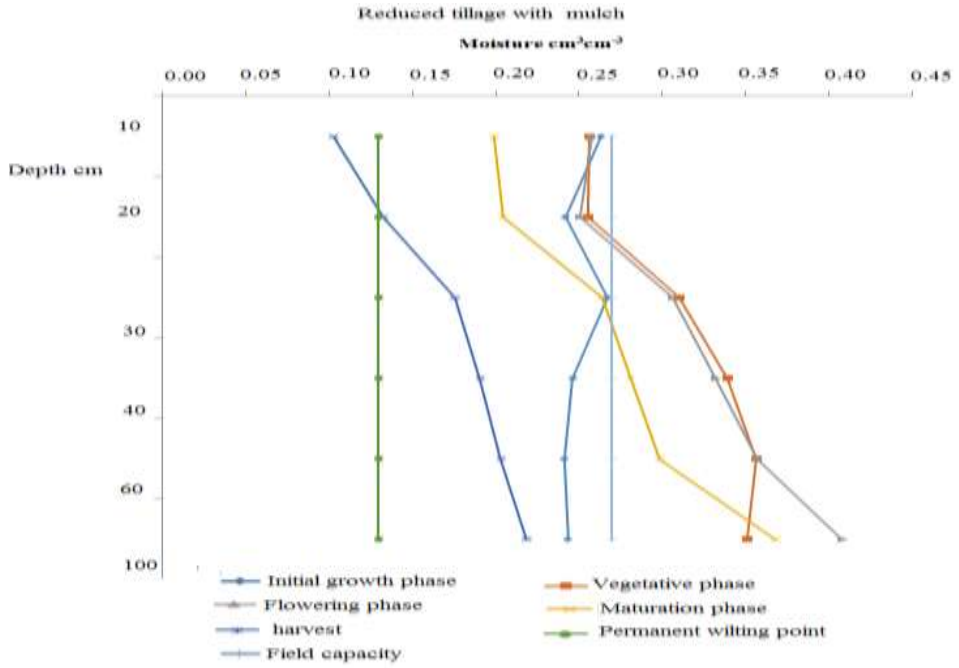
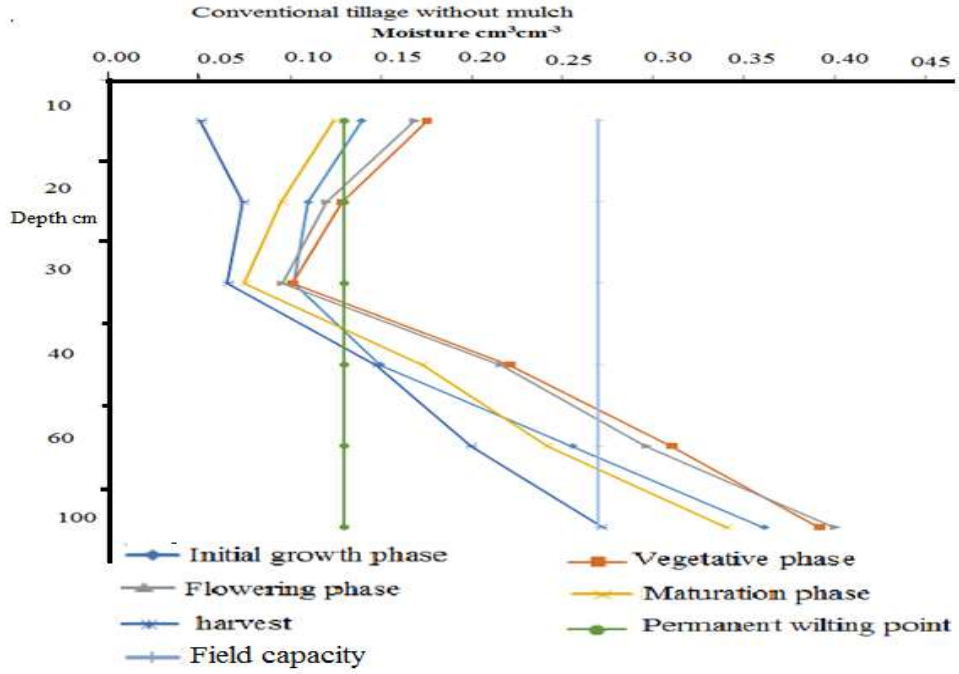


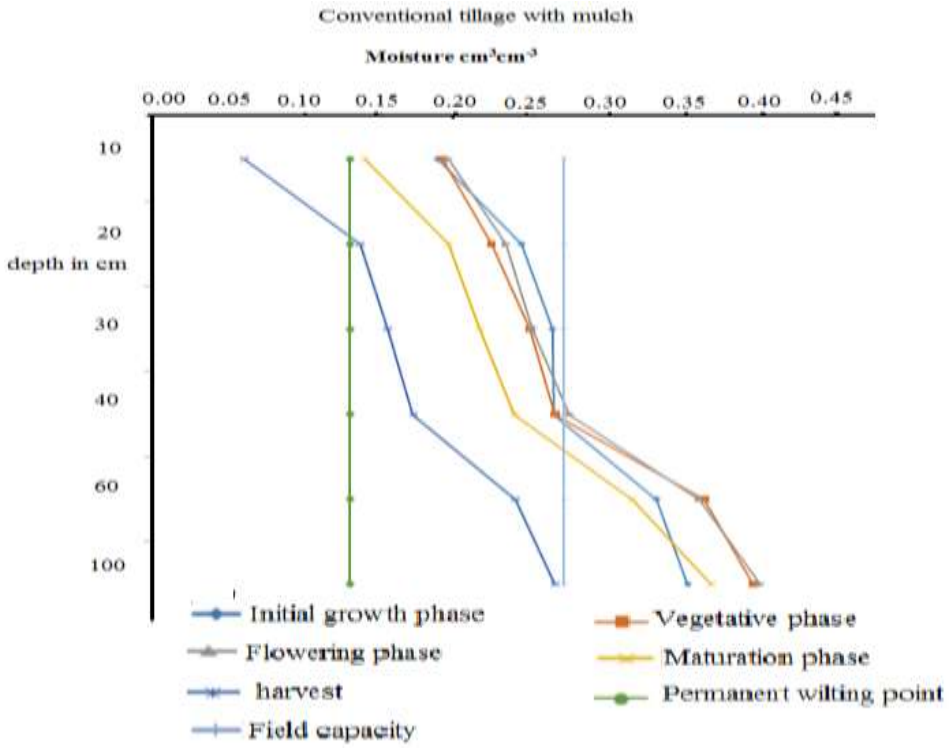
Fig 5: The average distribution of soil profile moisture content in conventional tillage without mulch



Figures 5 and 6 presented the seasonal moisture distribution in the soil profile of conventional tillage practices without and with mulch. In this case, the soil moisture content was below permanent wilting points up to 30 cm depth in non-mulched plots; whereas in mulched plots it was below FC up to 40 cm depth but above permanent wilting point. This showed that tillage enhanced the evaporation and infiltration, which caused the reduction in moisture in the upper layers, however mulching resulted in reduced evaporation loss which was responsible for higher moisture content in mulched plots. Similar results were reported by Halfmann *et al.*, (2005) regarding infiltration i.e virgin soils showed a much lower infiltration rate for the tension infiltrometer, while the

conventional tillage system showed higher infiltration rate.

Fig 6: **The average distribution of soil profile moisture content in conventional tillage with mulch**



Conclusions

Conventional tillage was detrimental to soil physical properties, as a result, less soil moisture was conserved in the upper soil profile in conservation tillage within none mulched plots.The availability of soil moisture in every mulched plot specifically with 10 and 15 t ha^{-1} dose of FYM was at optimum level. In no-till and conventional tillage the green water was above and below 60 cm, respectively. Soil moisture in mulched plots conserved more moisture in comparison to non-mulched plots. Reduced tillage with 15 t ha^{-1} FYM performed better than all other treatments in soil profile water storage and distribution.

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Interactive effects of reward system on academic achievement in Bareilly District of Uttar Pradesh

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Abstract

A study was conducted to evaluate the interactive effects of the reward system on academic achievement in the Bareilly District of Uttar Pradesh and suggest recommendations for policymakers. The present study was quasi-experimental. The subject of the study were the children from primary, junior high school, and secondary classes of Uttar Pradesh Secondary Education Board (UPSEB/CBSE) schools/colleges of Bareilly District of Uttar Pradesh. The subjects included students of both female and male gender from rural and urban localities under the course of the present research as respondents. Two blocks (one rural and urban each) of Bareilly (UP) were randomly selected for the present research. One school of each of the three standards viz. primary, junior high school, and secondary was randomly localized to grave the information. Finally, 10 (five girls and boys each) students from each school/ college were randomly selected as the respondent in the present research work. Thus a total of 60 students acted as the respondent in the present study. The data for the research was collected with the help of standardized or validated tests (validity 0.84 and Reliability 0.91). Statistics dealt with all aspects of this, including the planning of data collection in terms of the design of surveys and experiments. Computer software like SPSS version 17 (SPSS, 1998) and Microsoft Excel version 2007 (MS Office, 2016) were employed for statistical calculations. Based on the present study it can be recommended that an intrinsic achievement system should be implemented and boy students and students from rural localities needed attention to the improvement of achievements in the Bareilly District of Uttar Pradesh.

Key words: Achievements, Bareilly, Extrinsic, Intrinsic, Junior high school, Primary education, Rural, Secondary education, Urban

Introduction

The report, learning without burden notes that public examinations at the end of Class X and XII should be reviewed to replace the prevailing text-based and quiz-type questioning, which induces an inordinate level of anxiety and stress and promotes rote learning. While urban middle-class children are stressed by the need to perform extremely well, rural children are not sure whether their preparation is adequate even to succeed. The high failure rates, especially among the rural, economically weaker, and socially deprived children, force one to critically review the whole system of evaluation and examination. For if the system was fair and working adequately, there is no reason why children should not progress and learn.

Motivating students to achieve academically highlights the different philosophical debates over intrinsic versus extrinsic motivation. Educators want to know how motivation can be increased for middle-level students who often arrive at middle school with a predetermined attitude about their ability to succeed or fail. The fundamental competitive view of our economic system often dictates how many reward systems are organized to motivate students. Rather than finding

ways to recognize each student as an individual as suggested by middle school experts, teams often set out to develop systems that will manage both behaviour and academics by rewarding those who comply and punishing those who do not (Kohn, 1986; 1993; 1996).

Intrinsic motivation theory and research have a 40-year history beginning with White, (1959) who first challenged Skinner's empirical reinforcement theory with the theory of competence as a crucial element in motivation. Personal causation theory was developed by deCharms, (1968) as he researched young men's motivation to achieve measured against some internal standard of excellence. Bandura, (1982) proposed the theory of social learning and self-efficacy by studying peoples' self-regulation. This sense of self influences the choice of activity, how much effort one is willing to expend, and how persistent one will be in accomplishing a task. Deci and Ryan, (1986; 1992) provided evidence that extrinsically caused behaviour undermines motivation in the long run. Another aspect of self-efficacy is attribution theory, the individual's belief that persistence will get a job done (Lent, *et al.,* 1984; Schunk, 1989; Weiner, 1974). This research consistently demonstrates that a student's internal or intrinsic sense of self and belief in working hard to achieve a goal are the determining factors in whether or not he will succeed. More recent studies have focused on goal orientation and the idea that motivation is determined jointly by the expectation that the effort will lead to the goal (self-efficacy) and that the goal is worth attaining (Csikzentmihalyi and Nakamura, 1989; Patric *et al.,* 1999). Educators have a difficult task developing a single extrinsic reward system that will match the motivational needs of various people. Thus, offering ice cream coupons or pizza may motivate a few students to improve their academic performance in the short term.

External rewards, while still popular, generally have only a short-term positive effect and possible long-term negative effects on learning. When students have a sense of control and choice, on the other hand, and are challenged just above their level of competence, they have increased intrinsic motivation, persistence, and belief that they can be successful.

Materials and methods

The present study was quasi-experimental. The subject of the study were the children from primary, junior high school, and secondary classes of Uttar Pradesh Secondary Education Board (UPSEB/CBSE) schools/colleges of Bareilly District of Uttar Pradesh. The subjects included students of both female and male gender from rural and urban localities under the course of the present research as respondents. Once the variables have been identified and defined, a procedure should then be implemented and group differences should be examined (Gribbons, & Herman, 1997). All the students studying in primary, junior high school, and secondary classes of Uttar Pradesh Secondary Education Board (UPSEB) schools/colleges of the urban areas of Bareilly were contributing to the population. The up-to-date list of the government-added and un-added institutions providing primary, junior high school, and secondary education in District Bareilly was used as the source list to find out sampling units. The up-to-date list was available on the official website of the government of Uttar Pradesh (https:// www.bareilly.nic.in). The research was based on the subjects (samples). The samples were drawn based on simple random sampling during the present research work.

The urban area of Bareilly city is divided into five Tehsils and 15 Community Development Blocks wards. Two blocks (one rural and urban each) were randomly selected for the present research. One

school of each of the three standards viz. primary, junior high school, and secondary was randomly localized to grave the information. Finally, 10 (five girls and boys each) students from each school/ college were randomly selected as the respondent in the present research work. Thus a total of 60 students acted as the respondent in the present study. The research design is presented in the table 1.

Table 1: Research Design

Level	IA	EA	Boys	Girls	Rural	Urban	Total
Primary	10	10	10	10	10	10	5
Junior High School	10	10	10	10	10	10	5
Secondary	10	10	10	10	10	10	5
Total	**30**	**30**	**30**	**30**	**30**	**30**	**15**
IA-Intrinsic award system, EA-Extrinsic award system							

The independent variable of the present research was award systems whereas, the dependent variables were an achievement. In the present research, the research worker contacted randomly selected respondent children of the primary, junior high school, and secondary levels in various schools and colleges of the urban area of Bareilly city of the state of Uttar Pradesh individually and tried to be interrogated through appropriate tools. The data for the research was collected by the investigator with the help of standardized or validated tests.

To find out the reliability and validity of the test the questionnaire was administered over a sample of 90 students including classes 4, 7, and 9. The validity and reliability scores of the test were calculated using standard techniques. The reliability of the attitude Scale was determined by calculating the reliability coefficient on a sample of 90 subjects. The split-half reliability coefficient was found to be 0.84. Besides face validity, as well as items related to the variable under focus, the test has high content validity. It is evident from the assessment of judges that items of the scales were directly related to the concept of attitude Scaling. To find out the validity from the coefficient of reliability (Garret, 1981). The reliability index was calculated, which indicated high validity on account of being 0.91. Every item had three alternatives; out of them only one was correct and had a score of 2. Similarly, out of three alternatives; only one was incorrect and had a score of 0. The remaining alternative had a score of 1. The total score secured by the respondents was thus calculated based on the responses to the questionnaire that they attempted. Achievement tests were intended to evaluate the achievement in English of the students of standards IV, VII, and IX. The syllabus outlines of English for these standards prescribed by the NCERT were carefully analyzed. The content outlines taught in the classes were reviewed thoroughly. Textbooks, reference materials, question banks, question papers, and handbooks of English for three standards were utilized as sources for framing items. The achievement test questionnaires were developed after the review of a large number of related works of literature. The English textbooks were studied thoroughly and concepts were understood. Every chapter taught in the class was given importance and questions were selected with the help and advice of subject experts and also by choosing repeated questions by verifying many question banks. Both descriptive and objective items were placed while

constructing the questionnaire. The maximum marks for the achievement test were decided to be 40.

The investigator prepared the final lists of schools to be covered in the present research and visited these institutions frequently as and when needed. The respondents selected as a sample of the universe were handed over/read over the questionnaires with the request to return them with their responses to the surveyor as early as possible. The surveyor re-contacted the respondents and tried to find their responses on the non-responded items. Responses to the questionnaire were classified into various meaningful categories. Thus, the material is presented in a classified format.

Statistics is the study of the collection, organization, analysis, and interpretation of data. It deals with all aspects of this, including the planning of data collection in terms of the design of surveys and experiments. Computer software like SPSS version 17 (SPSS, 1998) and Microsoft Excel version 2007 (MS Office, 2016) were employed for statistical calculations under the supervision and operation of the expert.

Results and discussion

Achievement scores of the respondent students of various categories have been presented in table 2. The achievement test scores achieved by the respondents on an overall basis were 16.58±0.02 (median 16.63) with a standard deviation of 0.22 (minimum 8, maximum 24, and range 16) in 120 observations. The achievement test scores achieved by the respondents under the intrinsic award system were 16.95±0.02 (median 16.92) with a standard deviation of 0.18 (minimum 11, maximum 24, and range 13) in 60 observations whereas the scores under the extrinsic award system were 16.22±0.04 (median 16.25) with standard deviation 0.33 (minimum 8, maximum 24 and range 16) in 60 observations. The achievement test scores achieved by the respondents at the primary level were 17.78±0.28 (median 18.25) with a standard deviation of 1.78 (minimum 8, maximum 24, and range 16) in 40 observations, whereas the scores at the junior high school level were 17.18±0.2 (median 17.25) with standard deviation 1.28 (minimum 12, maximum 23 and range 11) in 40 observations and at secondary level were 14.8±0.27 (median 15.13) with standard deviation 1.70 (minimum 9, maximum 24 and range 15) in 40 observations. The achievement test scores achieved by the boy students were 16.13±0.11 (median 16.00) with a standard deviation of 0.83 (minimum 8, maximum 24, and range 16) in 60 observations whereas the scores achieved by the girl students were 17.03±0.09 (median 17.25) with standard deviation 0.73 (minimum 9, maximum 24 and range 15) in 60 observations. The achievement test scores achieved by the students from rural localities were 16.01±0.14 (median 16.00) with a standard deviation of 0.85 (minimum 8, maximum 26, and range 18) in 60 observations whereas the scores achieved by the urban localities were 17.16±0.10 (median 17.15) with standard deviation 0.76 (minimum 8, maximum 24 and range 16) in 60 observations.

The highest achievement test scores achieved by the respondents in the intrinsic award system at the primary level (20.00±0.26) followed by the intrinsic award system at the junior high school level, (17.25±0.42) extrinsic award system at the junior high school level (17.10±0.32), extrinsic award system at the secondary level (16.00±0.45), and extrinsic award system at primary level (15.55±0.65), whereas intrinsic award system at the secondary level recorded lowest achievements (13.60±0.46). The highest achievement test scores achieved by the respondents by girl students at the primary level (18.25±0.41) followed by girl students at the junior high school level, (17.64±0.46) boy students at the

primary level (17.29±0.44), boy students at the secondary level (16.71±0.45), and girl students at the secondary level (15.20±0.39), whereas boy students at the secondary level recorded lowest achievements (14.39±0.36). The highest achievement test scores achieved by the respondents from urban localities at the junior high school level (18.29±0.38) followed by urban localities at the primary level, (18.28±0.33) rural localities at the primary level (17.27±0.40), rural localities at junior high school level (16.06±0.26), and urban localities at the secondary level (14.91±0.46), whereas rural localities at the secondary level recorded lowest achievements (14.69±0.43).

Table 2: Comparative Achievement Test Scores of Respondents

Factors	Intrinsic/extrinsic		Boys/ Girls		Rural/ Urban		Overall
	Intrinsic	Extrinsic	Boys	Girls	Rural	Urban	
Primary	20.00 ±0.26	15.55 ±0.65	17.29 ±0.44	18.25 ±0.41	17.27 ±0.40	18.28 ±0.33	**17.78 ±0.28**
Junior High School	17.25 ±0.42	17.10 ±0.32	16.71 ±0.45	17.64 ±0.46	16.06 ±0.26	18.29 ±0.38	**17.18 ±0.20**
Secondary	13.60 ±0.46	16.00 ±0.45	14.39 ±0.36	15.20 ±0.39	14.69 ±0.43	14.91 ±0.46	**14.8 ±0.27**
Overall	16.95 ±0.02	16.22 ±0.04	16.13 ±0.11	17.03 ±0.09	16.01 ±0.14	17.16 ±0.10	**16.58 ±0.02**

Based on the present study it can be recommended that an intrinsic achievement system should be implemented and boy students and students from rural localities needed attention to the improvement of achievements in the Bareilly District of Uttar Pradesh.

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Oviposition and larval survival of diamondback moth (*Plutella xylostella*) on Indian mustard under protected field conditions

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Abstract

Incidence of Indian mustard var. Pusa Bold and Pusa Jaikisan on the oviposition of *Plutella xylostella* (Order Lepidoptera: Family, Plutellidae) has significantly (P<0.05) preferred to oviposit on cauliflower (control) as compared to Indian mustard in both choice and no-choice tests. In the choice test, females preferred to lay more eggs on Pusa Bold than on Pusa Jaikisan. In the experiment conducted in the month of October (2017-18), female oviposits significantly (P<0.05) highest number of eggs laid by *P. xylostella* was recorded in the month of October and the smallest in January 2017-18, and 2018-19 where 72.05 eggs/female on cauliflower. Fecundity of *P. xylostella* was found significantly (P<0.05) highest on cauliflower as compared to Indian mustard. Cauliflower received a maximum number of eggs (225.72) during the experiment in the month of October but fecundity tends to decrease from November to January. Pusa Bold is significantly (P<0.05) more preferred by female *P. xylostella* to lay eggs than that of Pusa Jaikisan. The Pusa Jaikisan may be more effective for integrated pest management of brassica crops.

Key words: Cauliflower, Indian mustard, *P. xylostella*, Pusa Bold, Pusa Jaikisan, oviposition

Introduction

India is the largest producer of vegetables in the world after China with an annual production of 101.43 million tonnes from 6.76 million ha of land (Rai and Pandey 2007). Cauliflower is most preferred winter vegetables and their total share in country's vegetable production is 6.1 and 4.4 percent, respectively (Anonymous 2005). The important insect pests associated with cauliflower are Diamondback moth (DBM), *Plutella xylostella* (Linn.) (Lepidoptera: Yponomeutidae) is a major and destructive insect pest of *Brassicaceous* crops worldwide (Sarfaraz *et al.,* 2005). Krishnakumar *et al.,* (1984) have estimated a 52 percent loss in marketable cabbage due to DBM attack while Srinivasan (1984) reported 90-92 percent loss could occur if cauliflower is left unprotected and also vary from 30-100 percent (Lingappa *et al.*, 2000). Whereas it causes an annual loss of US $ 16 million (Mohan and Gujar, 2003) and outbreaks of DBM in South East Asia sometimes have caused more than 90 percent losses (Talekar and Shelton 1993). Although diamondback moth outbreaks are sporadic, it is always present during the growing season, 1997 and 1998, Shanghai, China in 1992 and 1994 where losses were estimated to be 99 percent and 80 percent respectively (Zhao *et al.*, 1996), Kenya in 1995 (Kibata 1996), Western Australia in 2001 and New South Wales in 2002 (Endersby *et al.,* 2003). Use of intercropping provides an excellent

opportunity as an ecological approach in pest management. According Aung *et al.,* (2020) The Intercropping is one of the cultural control methods. It involves the cultivation of two or more crops simultaneously in the same field and intercropping can reduce pest population because of the diversity of crops grown. Intercropping affects the pest by microclimate through changes in crop canopies (Bach and Tabashnik, 1990, and Wu *et al.,* 1999). For some crop insect's situation in cropping has reduced pest population because the plants act as a physical barrier to the movement of pest insect. Natural enemies are more abundant and or the chemical or visual communication between pest insect and their host plant is disrupted (Risch 1981). The present study effect of Indian mustard on the oviposition and larval survival of diamondback moth were carried out to find a most suitable variety of brassica crops that can be used as potential management of *P. xylostella* under different condition.

Materials and methods

The experiment was conducted at the field Department of Plant Protection, Faculty of Agricultural sciences, A.M.U. Aligarh for two Rabi seasons: 2017 and 2018. Oviposition and larval survival of *P. xylostella* was studied on cauliflower and Indian mustard var. Pusa Bold and Pusa Jaikisan under protected field condition (no-choice test) for two consecutive years from 10th September of 2017-18 and 2018-19. Soil with farm yard manure (FYM) in a ratio of 3:1 and then they were kept under protected condition to avoid insect infestation. Thinning was done 30 days after sowing where only one plant is left in a single earthen pot and plants (40 days after sowing) were exposed to adults. Five potted host plants were kept under the nylon cage (1x1x1m) and five pairs of newly emerged adults obtained from the stock culture were released in the cage. Sugar solution soaked in cotton was kept inside the cage for feeding the adults. The host plants were removed from the cage after 24 hr and the experiment was replicated 10 times. The plants were then kept in cages covered with fine nylon netting under field condition so that parasites and predators may be avoided. 100 eggs were selected on the plants of known age for construction of stage specific life table. Hatched and unhatched eggs were counted. The same method was adopted for other host plants. Stage specific, fertility table and life indices were calculated as described earlier. Finally, the data was analyzed statistically by application of correlation, and ANOVA and further subjected to test of significance. Daily maximum and minimum temperatures were also recorded for two years with reference method of Wilson and Barnett (1983).

Results and discussion

Oviposition (Choice test): Pots containing plant of Pusa Bold, Pusa Jaikisan and a cauliflower were kept in a nylon cage measuring 1x1x1x mt and 5 pairs of adults of *P. xylostella* were released inside the cage and sugar solution socked in cotton also kept in the nylon cage. The potted plants were removed after 2 days of exposure and fresh pots containing above mentioned plants were introduced in cage and it was carried out till the death of adult respectively (Table 1) Eggs were counted on each plant and then calculated the average number of eggs/females. The experiment was replicated three times. The plants containing eggs were kept under protected condition for further observation. Ahmad *et al*., 2008 reported female diamondback moth laid 200 eggs on *Brassica juncea* in field condition while as 140-175 egg in laboratory condition

Oviposition (No-Choice test): Pots containing plant of Pusa Bold, Pusa Jaikisan and cauliflower were exposed individually for no-choice test. A single plant was kept under a nylon cage measuring 1x1x1mt and then one pair of adults was released into the cage for two

days along with sugar solution soaked in cotton as a food source for adult. The potted plant was removed from the cage and replaced by another potted plant for another two days and the same was repeated till the death of adults. Eggs were counted on the plant and these potted plants were kept under protected condition for further observation. Five replicates were made for each host plant i.e., Pusa Bold and Pusa Jaikisan and a parallel control for cauliflower was also run for each replicate.

Table 1: Effect of Indian mustard on the oviposition of *P. xylostella* under protected field condition

Host Cropping season 2017-18	Choice test		No-Choice test	
	Total no. of eggs / 5 females	Average no. of eggs / female	Total no. of eggs / 5 females	Average no. of eggs / female
Pusa Bold	185.76±2.92^{b}	37.15±1.18^{b}	624.82±2.34^{b}	124.96±1.76^{b}
Pusa Jaikisan	152.48±1.20^{a}	30.49±1.17^{a}	585.55±2.91^{a}	117.11±1.18^{a}
Cauliflower	685.24±2.93^{c}	137.04±2.32^{c}	1128.64±7.52^{c}	225.72±2.32^{c}
LSD *P*=0.05	3.03	0.98	6.57	1.75
Pusa Bold	168.24±1.75^{b}	33.64±1.17^{b}	528.22±1.74^{b}	105.64±1.75^{b}
Pusa Jaikisan	136.12±1.74^{a}	27.24±1.21^{a}	454.54±1.75^{a}	90.90±1.18^{a}
Cauliflower	504.68±1.76^{c}	100.93±2.93^{c}	1016.46±3.49^{c}	203.29±1.75^{c}
LSD *P*=0.05	1.87	0.71	5.94	1.25
Pusa Bold	134.42±1.74^{b}	26.88±1.20^{b}	448.32±1.74^{b}	89.66±1.75^{b}
Pusa Jaikisan	105.94±1.72^{a}	21.18±1.17^{a}	365.85±1.18^{a}	73.17±1.74^{a}
Cauliflower	415.56±1.74^{c}	83.11±2.92^{c}	813.92±4.65^{c}	162.78±1.17^{c}
LSD *P*=0.05	1.73	0.63	5.53	1.19
Pusa Bold	114.88±1.74^{b}	22.97±1.19^{b}	412.96±1.17^{b}	82.59±1.18^{b}
Pusa Jaikisan	85.54±1.75^{a}	17.11±1.17^{a}	285.38±1.74^{a}	57.07±1.18^{a}
Cauliflower	360.26±3.49^{c}	72.05±2.33^{c}	675.66±2.34^{c}	135.13±2.32^{c}
LSD *P*=0.05	1.67	0.57	4.18	1.08

Values not followed by same letter are significantly different (P=0.05) by DMRT

Analyzed result (Table 2) showed that female *P. xylostella* has significantly (*P*<0.05) preferred to oviposit on cauliflower (control) as compared to Indian mustard in both choice and no-choice tests. In choice test, females preferred to lay more eggs on Pusa Bold than to on Pusa Jaikisan. The experiment conducted in the month of October; female oviposits significantly (*P*<0.05) more eggs on Pusa Bold than Pusa Jaikisan but highest number of eggs deposited by female *P. xylostella* on cauliflower. Almost similar results obtained in the month of November, December and January. Fecundity of *P. xylostella* is considerably decreased from November to January. It is also found that highest of number of eggs laid by *P. xylostella* was recorded in the month of October, 2008 and smallest in January, 2009 where 76.52 eggs/female on cauliflower.

No-Choice test

Fecundity of *P. xylostella* was found significantly (*P*<0.05) highest on cauliflower as compared to Indian mustard. Cauliflower received maximum number of eggs (228.94) during the experiment in the month of October but fecundity tends to decrease from November to January. Pusa Bold is significantly (*P*<0.05) more preferred by female *P. xylostella* to lay eggs than that of Pusa Jaikisan. In the month of October, 125.75 eggs were laid by a female on Pusa Bold while, 118.47 eggs on Pusa Jaikisan. According some investigation that the

effect of intercropping to reduce infestation of diamondback moth on cabbage. (Karavina *et al*., 2014). They found that onion, tomato, garlic and chilli (pepper) can be used as intercrops to reduce DBM infestation on cabbage because of their repellent ability. Furthermore, mustard, Chinese cabbage and collard can also be used as trap crop (Singhamuni and Hemachandra 2013).

Table 2: Effect of Indian mustard on the oviposition of *P. xylostella* under protected field condition

Host Cropping season 2017-18	Choice test		No-Choice test	
	Total no. of eggs / 5 females	Average no. of eggs / female	Total no. of eggs / 5 females	Average no. of eggs / female
Pusa Bold	188.92±2.64^{b}	37.78±1.15^{b}	628.78±2.38^{b}	125.75±1.74^{b}
Pusa Jaikisan	156.84±2.12^{a}	31.36±1.18^{a}	5.92.38±2.82^{a}	118.47±1.62^{a}
Cauliflower	694.68±3.25^{c}	138.93±2.34^{c}	1144.68±6.82^{c}	228.94±2.34^{c}
LSD *P*=0.05	2.98	0.92	6.62	1.72
Pusa Bold	174.28±1.82^{b}	34.85±1.18^{b}	535.26±1.78^{b}	107.05±1.73^{b}
Pusa Jaikisan	142.18±1.78^{a}	28.43±1.24^{a}	462.46±1.64^{a}	92.49±1.16^{a}
Cauliflower	517.52±1.84^{c}	103.50±2.88^{c}	1034.62±3.62^{c}	206.92±1.74^{c}
LSD *P*=0.05	1.82	0.73	5.88	1.34
Pusa Bold	138.24±1.54^{b}	27.64±1.21^{b}	435.23±1.38^{b}	87.04±1.74^{b}
Pusa Jaikisan	112.88±1.48^{a}	22.57±1.18^{a}	372.92±1.52^{a}	74.58±1.73^{a}
Cauliflower	428.65±1.72^{c}	85.73±2.92^{c}	862.78±3.84^{c}	172.56±1.18^{c}
LSD *P*=0.05	1.76	0.65	5.46	1.22
Pusa Bold	119.64±1.65^{b}	23.92±1.18^{b}	418.62±1.24^{b}	83.72±1.18^{b}
Pusa Jaikisan	88.72±1.72^{a}	17.75±1.16^{a}	292.82±1.68^{a}	58.56±1.17^{a}
Cauliflower	382.62±3.38^{c}	76.52±2.34^{c}	686.74±2.45^{c}	137.34±2.34^{c}
LSD *P*=0.05	1.63	0.54	4.06	1.14

Values not followed by same letter are significantly different (P=0.05) by DMRT

Conclusion

Effect of Indian mustard var. Pusa Bold and Pusa Jaikisan on the oviposition of *P. xylostella* were concluded that preference of female diamondback moth for egg laying on cauliflower (control) as compared to Indian mustard in two different type tests choice and no-choice tests. In choice test, female lay more eggs on Pusa Bold than to on Pusa Jaikisan. Fecundity of *P. xylostella* was found highest on cauliflower as compared to Indian mustard. Cauliflower received maximum number of eggs during the experiment in the month of October but fecundity tends to decrease from November to January. The Indian mustard of different variety can be used trap crop in between cabbage and cauliflower production for management of diamondback moth. For advancement of rural areas and promote the use of Integrated pest management to avoid uses of chemical is necessary that farmers should be trained for intercropping of mustard crop for management of diamondback moth.

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Weed dynamics, weed control efficiency, crop growth and yield attributes of chickpea in response to chemical weed management

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Abstract

A field experiment was conducted at the Research Farm of the College of Agriculture, Banda University of Agriculture and Technology, Banda. The climate of this region is typically semi-arid, characterized by extremes of temperatures during both summers and winters. The experiment was conducted in a randomized complete block design (RCBD) with 10 treatment combinations of pre and post-emergence herbicides. Among herbicides pre-emergence application of Imazethapyr 40g alone or in combination with pendimethalin or oxyfluorfen significantly reduced weed density, and weed dry weight and proved efficient in managing sedge weeds. The highest weed control efficiency recorded at all three stages of crop growth was associated with Pendimethalin 1000g PE fb Imazethapyr 40g PoE. Application of Pendimethalin 1000g PE fb Quizalofop-ethyl 50g PoE markedly influenced the yield and yield attributes of chickpea.

Key words: Chemical Weed Management, Weed Dynamics, Chickpea, Growth, Yield Attributes

Introduction

Pulse owe important and diverse role in farming system as well as in the human diet in several developing and developed countries. Pulses contribute substantially to food production system by enriching the soil through biological nitrogen fixation and improving soil physical conditions. Among the grain legumes, chickpea (*Cicer arietinum* L.) is an important and unique food legume. Chickpea (*Cicer arietinum* L.) is one of the most important *rabi* (winter) pulse crop of India and occupies first position among the pulses. In India it is grown on acreage of 10.17 million hectares and producing 11.35 million tones with productivity of 1116 kg ha^{-1} during 2019-20. In Uttar Pradesh, chickpea is successfully cultivated on an area of 0.62 M ha with productivity of 1371 kg ha^{-1} (Anonymous, 2020).

In spite of the significance of this crop in human and animal diet average productivity of the crop in Uttar Pradesh and Bundelkhand region is low. The low productivity of this crop is due to various biotic and abiotic stresses. Among the various biotic stresses, weeds are the major one which causes severe yield loss in pulses. Due to initial slow growth of pulses, weeds emerge first and gain competitive advantage over the crop and exhibit smothering effect on crop. The early emergence and fast growth of the weeds lead to severe crop-weed competition for resources. Crop weed competition causes heavy reduction in growth and yield of chickpea and lessens the profitability Chopra *et al.,* (2003). About 40-45% reduction in yield of chickpea due to severe infestation of weeds is estimated Chaudhary *et al.*, (2005). The yield reduction due to weed invasion varied with the crop, weed density, critical period of crop weed competition, crop management and agro

climatic conditions. The initial 60 days period considered too critical for weed crop competition in chickpea Singh and Singh (2000), but continuously facing of the scarcity of labour and increase in labour cost, manual weed control has become a difficult task. Introduction of new molecules of herbicides has made it possible to control a wide spectrum of weeds in chickpea effectively at a remunerative cost. Keeping these facts in view, an investigation was under taken to test the performance of pre and post-emergence herbicides either alone or in combination in chickpea.

Materials and methods

Field experiment was conducted at Research Farm of College of Agriculture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh. The research farm of College of Agriculture, Banda University of Agriculture and Technology, Banda (U.P) is situated between Latitudes 24° 53′ and 25° 55′ N and Longitudes 80° 07′ and 81° 34′ E and having an altitude of 168m above mean sea level. The climate of this region is a typically semi-arid, characterized by extremes of temperatures during both summers and winters. All together crop during growing season received 47.1 mm rainfall in 4 rainy days. The soil of experimental field was silty clay (Inceptisols) shallow, flat, well drained and moderately fertile, being low in available organic carbon, phosphorus and high in potassium and sulphur.

Field experiment was conducted in randomized block design (RBD) with 10 treatments (Weedy check, weed free upto 60 DAS, Pendimethalin 1000g Pre emergence + 1HW, Oxyfluorfen 100g Pre-emergence +1 HW, Imezathapyr 40g 20 DAS as Post emergence, Quizalofop-ethyl 50g 25 to 30 DAS as Post emergence, Pendimethalin 1000g Pre emergence fb Imezathapyr 40g Post emergence, Pendimethalin 1000g Pre-emergence fb Quizalofop-ethyl 50g Post-emergence, Oxyfluorfen 100g Pre-emergence fb Imezathapyr 40g Post emergence, Oxyfluorfen 100g Pre emergence fb Quizalofop-ethyl 50g Post emergence. Chickpea variety JG 14 was used for sowing at spacing of 30x10 cm in 1st week of November 2019 by following standard agronomic practices. Treatments like pre-emergence herbicides were applied next day after sowing whereas post-emergence herbicides were applied 20 and 25 DAS as per treatment by using a Knapsack sprayer fitted with flat fan nozzle. Observations recorded as per need on weed and crop.

Results and discussion

In experimental field all together 10 major weeds observed (Table 1). The important weed species that were found to infest the experimental field were *Cynodon dactylon, Cyperus rotundus, Eclipta alba, Digera arvensis, Chenopodium album, Anagalis arvensis, Chenopodium murale, Euphorbia dracunculoides, Asphodelus tenuifolius* and *Vicia sativa*. Survey of the experimental field exposed that weedy check plots were heavily invaded by *Cyperus rotundus* (116.3 m^{-2}) followed by broad leaved weeds (29.3 m^{-2}) and *Cynodon dactylon* (4.3 m^{-2}). Among several broad leaf weeds *Eclipta alba* observed in majority. Other broad leaf weeds were *Digera arvensis, Chenopodium album, Anagalis arvensis, Chenopodium murale, Euphorbia dracunculoides, Asphodelus tenuifolius* and *Vicia sativa*. Density of *Eclipta alba* dominating weed species among broad leaves efficiently suppressed by application of Imazethapyr, Pendimethalin and Oxyfluorfen alone or in combination.

Among three categories of weeds were present in experimental field sedges were in majority followed by BLWs and NLWs. Similar observations also reported by Kumar *et al*., (2015). Density of broad-leaved weeds reduced significantly by application of Pendimethalin 1000g PE *fb* Imazethapyr 40g PoE (T_7) similarly drastic reduction in density of grassy weeds noted when herbicide Quizalofop-ethyl 50g PoE (T_6) applied during 20-25 DAS. At harvest

number of *Cyperus rotundus* were 29.7, 31 and 32.7 m^{-2} under weed control treatments *viz* Pendimethalin 1000g PE *fb* Imazethapyr 40g PoE (T_7), Imazethapyr 40g PoE (T_5) alone and Oxyfluorfen100g PE *fb* Imazethapyr 40g PoE (T_9), respectively proved efficient in managing of sedge weeds (Table 2). Marked difference was observed in total weed density (m^{-2}) with various weed control measures. Among the herbicidal treatments lowest total weed density (37 m^{-2}) was observed with the application of Pendimethalin 1000g PE *fb* Imazethapyr 40g PoE (T_7) which was found on par to Oxyfluorfen100g PE *fb* Imazethapyr 40g PoE (T_9) and significantly superior over rest of the treatments. This might be due to its broad-spectrum control. The mode of action of Imazethapyr inhibits ALS or AHAS enzymes responsible for the synthesis of three branched chain amino acids such as leusine, isoleusine and valine. Similarly, pre and post emergence application of herbicides found effective against grassy weeds.

Weed dry weight produced under weed free condition was lowest (2.6g) while it was highest (31.2g) under weedy check condition. Among the herbicidal treatments the lowest weed dry weight (10.0 g) was recorded with the application of Pendimethalin 1000g PE *fb* Imazethapyr 40g PoE (T_7) which was statistically at par with Pendimethalin 1000g PE *fb* 1 HW (T_3), Pendimethalin 1000g PE *fb* Quizalofop-ethyl 50g PoE (T_8) and Oxyfluorfen100g PE *fb* Imazethapyr 40g PoE (T_9) and found significantly superior over rest of the treatments (T_4, T_5, T_6 and T_{10}). Difference in weed dry weight was as per control exerted by several treatments on weeds. Accumulation of poor dry matter of weeds due to reduced weed density through effective destruction of weeds. On the other hand, inhibition of germination and growth of weeds following application of different herbicides might have reduced the weed growth through arresting different metabolic activities and thus causing mortality of weeds and ultimately reducing weed dry weight.

Among the different weed management practices, highest weed control efficiency of 100% at 60 DAS, 93.9 % at 90 DAS and 91.6 % at harvest, observed with the treatment T_2 (weed free). Among several herbicidal treatments maximum weed control efficiency at all the stages of crop growth observed with T_7 (Pendimethalin 1000g PE *fb* Imazethapyr 40g PoE) which was closely followed by T_3 (Pendimethalin 1000g PE *fb* 1 HW) at 60 and 90 DAS and at harvest. It is evident from the data that with advancement of crop stage weed control efficiency decreased gradually. At 60 DAS and 90 DAS maximum WCE was 77.4 % noticed under it was observed significantly superior over rest of the treatments. Maximum WCE 76.5, 73.2 and 68.0 % obtained under Pendimethalin 1000g PE *fb* Imazethapyr 40g PoE (T_7) which was statistically on par with Pendimethalin 1000g PE *fb* 1 HW (T_3) and Pendimethalin 1000g PE *fb* Quizalofop-ethyl 50g PoE (T_8). This is due to eliminations of all types of weeds either by hand weeding or application of herbicides in these treatments. This is well proven fact that as weed dry weight decreased weed control efficiency increased. Treatment which gave poor weed control efficiency produced more weed dry weight than other treatments.

Among the different weed management practices, taller plant (39.3cm), maximum number of branches (6.6 nos.) and higher dry matter accumulation (19.5g/plant) was associated with Pendimethalin 1000g PE *fb* Quizalofop-ethyl 50g PoE (T_8). The increase in growth character under Pendimethalin 1000g PE *fb* Quizalofop-ethyl 50g PoE treated conditions might be attributed due to the reduction in crop weed competition, reduced nutrient removal by weeds and provides better environment for growth and development of crop. Vivek *et al.*, (2008) was of the opinion that reduced crop weed

competition leads to enhanced growth attributes.

Various weed control parameters exert marked influence on number of pods per plant (31.6 nos.), seeds per pod (1.2 nos.) and higher seed index (25g) while influence was non-significant. Higher value of seed /pod and test weight was associated with T_2 (Weed Free) and T_8 (Pendimethalin 1000g PE *fb* Quizalofop-ethyl 50g PoE) while minimum with weedy check. The efficient weed control measures reduced weed density and biomass resulting in improvement of yield related traits. Many reports support such role of herbicide application in improving the yield related traits through efficient weed management Chander *et al.*, (2014).

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Effect of different levels of phosphorous and biofertilizers on growth and yield attributes of the blackgram (*Vigna mungo* L.) in the Grid Region

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Abstract

A field experiment was conducted to determine the effect of different levels of Phosphorous and biofertilizers on the growth and yield attributes of blackgram (Vigna mungo L.). The soil of the experimental field was sandy loam in texture with low content of organic matter and accessible nitrogen, medium in available potash and phosphorous. The field experiment was carried out during Kharif 2021 to test three phosphorous Levels (45, 60, and 75 Kg ha^{-1}) and three biofertilizers (Rhizobium, PSB, and Azospirillum) with absolute control. Thus, a Randomized Block Design with 10 treatments and 3 Replications was employed. Other recommended agronomical practices administered in all the treatments were similar. The growth, yield attribute, and yield in the plots treated with 75 Kg P_2O_5 ha^{-1}+ Rhizobium were higher than other treatments but at par with 60 Kg P_2O_5 ha^{-1}+ Rhizobium. Therefore, according to economics 60 Kg, of P_2O_5 ha^{-1}+Rhizobium may be recommended as the best dose for the cultivation of blackgram in the Grid region.

Keywords: *Azospirillum*, Biofertilizers, Blackgram, Phosphorous levels, Phosphate solubilizing Bacteria, PSB, *Rhizobium*

Introduction

Pulses are known as the wizard of the health+, and their nomenclature pulse (P = People, U = Umbrella, L = Animals, S = Soil, E = Energy). Pulse crops provide superb energy and are symbiotic as an umbrella for people as dietary proteins, further pulse crops are a boon to livestock as it is a source of green nutritious fodder and feed for soil as these enrich the soil by working as a mini-nitrogen plant and green manure (Ajewole, 2002). Pulses belong to the Leguminosae family commonly known as Fabaceae. The word pulse refers exclusively to the dried seed. The term "pulse" is derived from the Latin word "puls," meaning thick soup, potage, or broth (Keshavarz *et al.*, 2020). It is a solitary crop that is collected as a dry seed. Important pulse crops produced in India included gram (Chickpea), urd been (blackgram), Moong bean (green gram), Pigeon pea (red gram), and Masur (lentils). Pulses are typically utilized as dietary protein for vegetarians. Pulses contain approximately 21–25% protein; however, have a limiting amount of essential amino acids such as methionine, tryptophan, and cystine (Tiwari and Singh 2012). Pulse grains are an excellent source of protein, carbohydrates, dietary fibre, vitamins, minerals, and phytochemicals (Singh 2017). Pulses protein is high in Lysine holding an average of 65.7 mg g $protein^{-1}$. The total blackgram production in India was 2.89 million tonnes from an area of 3.56 million hectares. Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal, Punjab, Haryana, Tamil Nadu, Karnataka, Odisha, and Gujarat. Are important blackgram-producing states in India. In Madhya Pradesh, the total area was 9.32 lakh hectares with a total production of 515 million tonnes and productivity of 553 kg

ha^{-1} (MoAFW 2017). Blackgram (*Vigna mungo* L.) belongs to the family "Leguminosae" and sub-family "Papilionaceous" and has the chromosome number 2n=24. Cultivated blackgram (also known as urd, urad, or mash; *Vigna mungo* var. *mungo* (L.) Hepper) is believed to have been domesticated in India from its wild progenitor, *Vigna mungo* var. *silvestris* Lukoki, Maréchal, and Otoul (Chandel *et al.,* 1984).

Phosphorous is an essential constituent of every living cell. Phosphorous is the most vital nutrient for plant growth and development. In Indian soils, the amount of phosphorus is low to medium. Phosphorus is referred to as the "kingpin" in Indian agriculture and also as the "energy currency" of plants (Dey *et al.,* 2017). Phosphorous comprises important components of ATP and it works as the energy unit of plants. At the moment of photosynthesis, ATP will develop, it contains phosphorous in its structure. Phosphorous also supports the appropriate growth of root and root nodules to increase nitrogen fixation and which helps to build crop quality and resistance to plant disease (Scheublin *et al.,* 2004). This procedure is from the commencement of seedling development up to the creation of grain and maturity. Phosphorous also supports the appropriate growth of root and root nodules to increase nitrogen fixation and which helps to build crop quality and resistance to plant disease. Phosphorous is the most vital nutrient for plant growth and development. In Indian soils, the amount of phosphorus is low to medium (Pattanayak *et al.,* 2009).

Suhag (2016) described that biofertilizers are compounds that contribute nutrients via the natural process of fixing atmospheric nitrogen, solubilizing phosphorous, and aid for plant development through the manufacture of growth-encouraging material. Examples: *Rhizobium*, PSB (Phosphate solubilizing bacteria), *Azospirillum*, etc., *Rhizobium* is a symbiotic bacterium that helps to fix atmospheric nitrogen in connection with the roots of legumes and higher plants. It is a genus of Gram-negative bacteria. The effect of this symbiosis is to create nodules (Delves *et al.,* 1986) on the plant root where it transforms air nitrogen into ammonia that may be utilized by the plant. Rhizobia are a group of soil bacteria that infect the roots of legume plants which leads to the creation of root nodules where they fix nitrogen gas (N_2) from the atmosphere transforming it into the beneficial form of nitrogen for plants. PSB (Phosphate solubilizing bacteria) biofertilizer assists plants by transforming an insoluble form of phosphorous into a soluble form and scavenging phosphate from soil layers (Rawat *et al.,* 2021). It aids in promoting the life cycle of micro-organisms in the soil which are capable of converting insoluble phosphorous and making it accessible for crops by secreting specific organic acids resulting in a decrease in soil pH. Different forms of organic acids, including citric acid, gluconic acid, lactic acid, succinic acid, propionic acid, and three more unknown organic acids were formed from the cultures of these isolates (Selvakumar 2012). And it also helps to prevent fungal illnesses by demonstrating anti-fungal activities. *Azospirillum* is a free-living Gram-negative bacterium that fixes atmospheric nitrogen for plant growth and development (Steenhoudt and Vanderleyden 2000). It is a non-photosynthetic bacterium that may thrive in aerobic, microaerobic, and anaerobic environments. It helps to synthesize phytohormones like Indole-3-acetic acid and is thought to boost biotic and abiotic stress tolerance capability thereby aiding in plant development.

Materials and methods

The experiment was carried out at the School of Agriculture, ITM University Gwalior, (M.P.) during the Kharif season of 2020-21. The experiment was

conducted factorial randomized block design with ten treatments and three replications. In the experiment phosphorous was applied according to different levels and biofertilizers were applied as seed treatment as mentioned in the treatments, whereas nitrogen and potassium were applied as a recommended dose of fertilizer. The treatments under studied were Control, 45 Kg P_2O_5 ha^{-1} + *Rhizobium*, 45 Kg P_2O_5 ha^{-1} + PSB, 45 Kg P_2O_5 ha^{-1} + *Azospirillum*, 60 Kg P_2O_5 ha^{-1} + *Rhizobium*, 60 Kg P_2O_5 ha^{-1} + PSB, 60 Kg P_2O_5 ha^{-1} + *Azospirillum*, 75 Kg P_2O_5 ha^{-1} + *Rhizobium*, 75 Kg P_2O_5 ha^{-1} + PSB, 75 Kg P_2O_5 ha^{-1} + *Azospirillum*. The gross and net plot size was 4.5 m x 4.5 m and 3.5 m x 3.9 m^2, respectively. All other agronomic practices were practiced uniformly for all the treatments. Sowing is done by dibbling by using the seed rate is used 15-20 kg ha^{-1}. Spacing for sowing row to row 30 cm and plant to plant 10 cm. The recommended dose of fertilizer was 30:60:25 N:P:K kg ha^{-1} applied as per treatment and other cultural practices like gap filling, thinning and weeding done as per the schedule of days. Statistical analysis of the data was carried out by using Two Way ANOVA (Panse and Sukhantme 1967).

Result and discussion

The effect of different levels of phosphorous and biofertilizers on the growth attributes of a blackgram at harvest have been presented in Table 1. The maximum plant height ($p<0.05$) recorded from the plot which was treated with 75 Kg P_2O_5 ha^{-1} (57.4 cm) was at par with 60 Kg P_2O_5 ha^{-1} (53.9 cm) and significantly superior to 45 Kg P_2O_5 ha^{-1}(48.7 cm). As far as the biofertilizers are concerned, significantly superior plant height ($p<0.05$) was recorded from the plot given *Rhizobium* (57.0 cm) and PSB (54.5 cm) compared to that given *Azospirillum* (48.5 cm). The inferior plant height was recorded in absolute control (39.5 cm) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The effectiveness of phosphorous on the number of leaves was observed more effective ($p<0.05$) in the plots treated with 75 Kg P_2O_5 ha^{-1} (22.5 $plant^{-1}$) and 60 Kg P_2O_5 ha^{-1} (21.0 $plant^{-1}$) compared to that with 45 Kg P_2O_5 ha^{-1} (19.2 $plant^{-1}$). *Rhizobium* (21.7 $plant^{-1}$) and PSB (21.6 $plant^{-1}$) were also recorded as superior ($p<0.05$) compared to the *Azospirillum* treatment (19.4 $plant^{-1}$) in the blackgram. The number of leaves $plant^{-1}$ was recorded lower in the absolute control (17.7 $plant^{-1}$). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. Regarding leaf area, 75 Kg P_2O_5 ha^{-1} (39.9) and 60 Kg P_2O_5 ha^{-1} (36.9) applications reported better results ($p<0.05$) compared to 45 Kg P_2O_5 ha^{-1} (33.3). The maximum leaf area ($p<0.05$) was recorded from the plot treated with *Rhizobium* (39.6) and PSB (37.1) in comparison to the application of *Azospirillum* in the crop (33.3). A low leaf area was recorded in absolute control (29.8). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The response of regime of 75 Kg P_2O_5 ha^{-1} (5.99 $plant^{-1}$) and 60 Kg P_2O_5 ha^{-1} (5.37 $plant^{-1}$) on the number of branches was noted better ($p<0.05$) than that of 45 Kg P_2O_5 ha^{-1} (4.31 $plant^{-1}$). The regime of *Rhizobium* (5.74 $plant^{-1}$) and PSB (5.43 $plant^{-1}$) was better ($p<0.05$) than that of *Azospirillum* (4.49 $plant^{-1}$) on the number of branches. Absolute control (3.22 $plant^{-1}$) reported inferior results ($p<0.05$) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The effectiveness of phosphorous on the number of nodules was observed more effective ($p<0.05$) in the plots treated with 75 Kg P_2O_5 ha^{-1} (24.5 $plant^{-1}$) and 60 Kg P_2O_5 ha^{-1} (22.5 $plant^{-1}$) compared to that with 45 Kg P_2O_5 ha^{-1} (20.3 $plant^{-1}$). *Rhizobium* (24.4 $plant^{-1}$) and PSB (22.8

plant^{-1}) were also recorded as superior ($p<0.05$) compared to the *Azospirillum* treatment (20.2 plant^{-1}) in the blackgram. The number of nodules was recorded lower ($p<0.05$) in the absolute control (17.8 plant^{-1}). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. For nodules dry weight, 75 Kg P_2O_5 ha^{-1} (15.0 mg) and 60 Kg P_2O_5 ha^{-1} (14.6 mg) applications reported better results ($p<0.05$) compared to 45 Kg P_2O_5 ha^{-1} (12.6 mg). The response to the effect of Biofertilizers on nodule dry weight, higher results ($p<0.05$) were recorded from the plots treated with *Rhizobium* (15.1 mg) and PSB (14.2 mg) in comparison to the application of *Azospirillum* in the crop (12.9 mg). A low leaf area ($p<0.05$) was recorded in absolute control (11.0 mg) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The response of administration of 75 Kg P_2O_5 ha^{-1} (430 g m^{-2}) and 60 Kg P_2O_5 ha^{-1} (386 g m^{-2}) on dry matter accumulation was noted better ($p<0.05$) than that of 45 Kg P_2O_5 ha^{-1} (340 g m^{-2}). The administration of *Rhizobium* (422 g m^{-2}) and PSB (390 g m^{-2}) was better ($p<0.05$) than that of *Azospirillum* (344 g m^{-2}) on dry matter accumulation. Absolute control (288 g m^{-2}) reported inferior results ($p<0.05$) in this respect. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect.

Table 1: Effect of different levels of phosphorous and biofertilizers on growth attributes of blackgram at harvest

Treatments	Plant height (cm)	Leaf area (m^2)	No. of leaves (Plant^{-1})	No. of branches (Plant^{-1})	No. of Nodules (Plant^{-1})	Nodules dry weight (mg)	Dry matter accumulation (g m^{-2})
Phosphorous Levels (Kg ha^{-1}) [P]							
45	48.7	33.3	19.2	4.31	20.3	12.6	340
60	53.9	36.9	21.0	5.37	22.5	14.6	386
75	57.4	39.9	22.5	5.99	24.5	15.0	430
SEm±	1.5	1.2	0.6	0.16	0.8	0.4	15
CD (P=0.05)	4.4	3.5	1.7	0.46	2.0	1.2	44
Biofertilizers [B]							
Rhizobium	57.0	39.6	21.7	5.74	24.4	15.1	422
PSB	54.5	37.1	21.6	5.43	22.8	14.2	390
Azospirillum	48.5	33.3	19.4	4.49	20.2	12.9	344
SEm±	1.5	1.2	0.6	0.16	0.7	0.4	15
CD (P=0.05)	4.4	3.5	1.7	0.46	2.0	1.2	44
Control	39.5	29.8	17.7	3.22	17.8	11.0	288
P X B							
SEm±	2.6	2.1	1.0	0.27	1.2	0.72	26
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

The effect of different levels of phosphorous and biofertilizers on yield attributes and yield of blackgram at harvest have been presented in Table 2. The effectiveness of phosphorous on the number of pods was observed more effective ($p<0.05$) in the plots treated with 75 Kg P_2O_5 ha^{-1} (32. 9 Plant^{-1}) and 60 Kg P_2O_5 ha^{-1} (30.7 Plant^{-1}) compared to that with 45 Kg P_2O_5 ha^{-1} (26.0 Plant^{-1}).

Rhizobium (32.7 Plant^{-1}) and PSB (30.5 Plant^{-1}) were also recorded as superior ($p<0.05$) compared to the *Azospirillum* treatment (26.5 Plant^{-1}) in the blackgram. The number of pods was recorded lower in the absolute control (19.7 Plant^{-1}). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The response of regime of 75 Kg P_2O_5 ha^{-1} (6.67 Pod^{-1}) and 60 Kg P_2O_5 ha^{-1} (6.30 Pod^{-1}) on the number of grains was noted better ($p<0.05$) than that of 45 Kg P_2O_5 ha^{-1} (5.26 Pod^{-1}). The regime of *Rhizobium* (6.69 Pod^{-1}) and PSB (6.41 Pod^{-1}) was better ($p<0.05$) than that of *Azospirillum* (5.13 Pod^{-1}) on the number of grains. Absolute control (2.55 Pod^{-1}) reported inferior results ($p<0.05$) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. For test weight (1000 seeds), 75 Kg P_2O_5 ha^{-1} (38.0 g) and 60 Kg P_2O_5 ha^{-1} (35.8 g) applications reported better results ($p<0.05$) compared to 45 Kg P_2O_5 ha^{-1} (32.7 g). The response of the effect of Biofertilizers on test weight (1000 seeds) may be explained that the higher results ($p<0.05$) were recorded from the plots treated with *Rhizobium* (36.8 g) and PSB (36.6 g) in comparison to the application of *Azospirillum* in the crop (33.1 g). A low leaf area ($p<0.05$) was recorded in absolute control (29.8 g) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The maximum grain yield ($p<0.05$) recorded from the plot which was treated with 75 Kg P_2O_5 ha^{-1} (971 Kg ha^{-1}) which was at par with 60 Kg P_2O_5 ha^{-1} (962 Kg ha^{-1}) and significantly superior to 45 Kg P_2O_5 ha^{-1} (841 Kg ha^{-1}). As far as the biofertilizers are concerned, significantly superior grain yield ($p<0.05$) was recorded from the plot given *Rhizobium* (968 Kg ha^{-1}) and PSB (962 Kg ha^{-1}) compared to that given *Azospirillum* (843 Kg ha^{-1}). The inferior plant height was recorded in absolute control (514 Kg ha^{-1}) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The response of administration of 75 Kg P_2O_5 ha^{-1} (1191 Kg ha^{-1}) and 60 Kg P_2O_5 ha^{-1} (1123 Kg ha^{-1}) on stover yield was noted better ($p<0.05$) than that of 45 Kg P_2O_5 ha^{-1} (1013 Kg ha^{-1}). The administration of *Rhizobium* (1156 Kg ha^{-}) and PSB (1136 Kg ha^{-1}) was better ($p<0.05$) than that of *Azospirillum* (1036 Kg ha^{-1}) on stover yield. Absolute control (952 Kg ha^{-1}) reported inferior results ($p<0.05$) in this respect. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. Regarding biological yield, 75 Kg P_2O_5 ha^{-1} (2161 Kg ha^{-1}) and 60 Kg P_2O_5 ha^{-1} (2084 Kg ha^{-1}) applications reported better results ($p<0.05$) compared to 45 Kg P_2O_5 ha^{-1} (1854 Kg ha^{-1}). The maximum biological yield ($p<0.05$) was recorded from the plot treated with *Rhizobium* (2124 Kg ha^{-1}) and PSB (2097 Kg ha^{-1}) in comparison to the application of *Azospirillum* in the crop (1879 Kg ha^{-1}). A low leaf area was recorded in absolute control (1466 Kg ha^{-1}). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The effectiveness of phosphorous on harvest index was observed more effective ($p<0.05$) in the plots treated with 75 Kg P_2O_5 ha^{-1} (44.9 %) and 60 Kg P_2O_5 ha^{-1} (46.1 %) compared to that with 45 Kg P_2O_5 ha^{-1} (45.3 %). *Rhizobium* (45.6 %) and PSB (45.9 %) were also recorded as superior ($p<0.05$) compared to the *Azospirillum* treatment (44.9 %) in the blackgram. The harvest index was recorded lower ($p<0.05$) in the absolute control (35.0 %). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. Present findings confirmed the results of Kant *et al.,* (2016) who studied the effect of the use of various levels of phosphorus and different bio-fertilizers in combination.

The effect of different levels of phosphorous and biofertilizers on yield attributes and yield of blackgram at harvest have been presented in Table 2. The effectiveness of phosphorous on harvest index was observed more effective ($p<0.05$) in the plots treated with 75 Kg P_2O_5 ha^{-1} (44.9 %) and 60 Kg P_2O_5 ha^{-1} (46.1 %) compared to that with 45 Kg P_2O_5 ha^{-1} (45.3 %). *Rhizobium* (45.6 %) and PSB (45.9 %) were also recorded as superior ($p<0.05$) compared to the *Azospirillum* treatment (44.9 %) in the blackgram. The harvest index was recorded lower ($p<0.05$) in the absolute control (35.0 %). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The maximum grain yield ($p<0.05$) recorded from the plot which was treated with 75 Kg P_2O_5 ha^{-1} (971 Kg ha^{-1}) which was at par with 60 Kg P_2O_5 ha^{-1} (962 Kg ha^{-1}) and significantly superior to 45 Kg P_2O_5 ha^{-1} (841 Kg ha^{-1}). As far as the biofertilizers are concerned, significantly superior grain yield ($p<0.05$) was recorded from the plot given *Rhizobium* (968 Kg ha^{-1}) and PSB (962 Kg ha^{-1}) compared to that given *Azospirillum* (843 Kg ha^{-1}). The inferior plant height was recorded in absolute control (514 Kg ha^{-1}) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The response of regime of 75 Kg P_2O_5 ha^{-1} (6.67 Pod^{-1}) and 60 Kg P_2O_5 ha^{-1} (6.30 Pod^{-1}) on the number of grains was noted better ($p<0.05$) than that of 45 Kg P_2O_5 ha^{-1} (5.26 Pod^{-1}). The regime of *Rhizobium* (6.69 Pod^{-1}) and PSB (6.41 Pod^{-1}) was better ($p<0.05$) than that of *Azospirillum* (5.13 Pod^{-1}) on the number of grains. Absolute control (2.55 Pod^{-1}) reported inferior results ($p<0.05$) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The response of administration of 75 Kg P_2O_5 ha^{-1} (1191 Kg ha^{-1}) and 60 Kg P_2O_5 ha^{-1} (1123 Kg ha^{-1}) on stover yield was noted better ($p<0.05$) than that of 45 Kg P_2O_5 ha^{-1} (1013 Kg ha^{-1}). The administration of *Rhizobium* (1156 Kg ha^{-}) and PSB (1136 Kg ha^{-1}) was better ($p<0.05$) than that of *Azospirillum* (1036 Kg ha^{-1}) on stover yield. Absolute control (952 Kg ha^{-1}) reported inferior results ($p<0.05$) in this respect. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. Regarding biological yield, 75 Kg P_2O_5 ha^{-1} (2161 Kg ha^{-1}) and 60 Kg P_2O_5 ha^{-1} (2084 Kg ha^{-1}) applications reported better results ($p<0.05$) compared to 45 Kg P_2O_5 ha^{-1} (1854 Kg ha^{-1}). The maximum biological yield ($p<0.05$) was recorded from the plot treated with *Rhizobium* (2124 Kg ha^{-1}) and PSB (2097 Kg ha^{-1}) in comparison to the application of *Azospirillum* in the crop (1879 Kg ha^{-1}). A low leaf area was recorded in absolute control (1466 Kg ha^{-1}). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. For test weight (1000 seeds), 75 Kg P_2O_5 ha^{-1} (38.0 g) and 60 Kg P_2O_5 ha^{-1} (35.8 g) applications reported better results ($p<0.05$) compared to 45 Kg P_2O_5 ha^{-1} (32.7 g). The response of the effect of Biofertilizers on test weight (1000 seeds), the higher results ($p<0.05$) were recorded from the plots treated with *Rhizobium* (36.8 g) and PSB (36.6 g) in comparison to the application of *Azospirillum* in the crop (33.1 g). A low leaf area ($p<0.05$) was recorded in absolute control (29.8 g) in this regard. The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. The effectiveness of phosphorous on the number of pods was observed more effective ($p<0.05$) in the plots treated with 75 Kg P_2O_5 ha^{-1} (32. 9 $Plant^{-1}$) and 60 Kg P_2O_5 ha^{-1} (30.7 $Plant^{-1}$) compared to that with 45 Kg P_2O_5 ha^{-1} (26.0 $Plant^{-1}$). *Rhizobium* (32.7 $Plant^{-1}$) and PSB (30.5 $Plant^{-1}$) were also recorded as superior ($p<0.05$) compared to the *Azospirillum*

treatment (26.5 Plant^{-1}) in the blackgram. The number of pods was recorded lower in the absolute control (19.7 Plant^{-1}). The interaction between various phosphorus levels and biofertilizers remained nonsignificant ($p>0.05$) in this respect. Ananda *et al.,* (2014) reported that the application of phosphorus responded favorably up to 50 kg ha^{-1} for yield attributes, grain, and straw yield. The variation in this regard may be due to different soil fertility. In the present study, the soil fertility in terms of soil nitrogen, available phosphorus, and organic carbon was low. Present findings confirmed the results of Kant *et al.,* (2016) who studied the effect of the use of various levels of phosphorus and different bio-fertilizers in combination. The maximum value of yield attributes and seed yield of blackgram was obtained with the application of 75 kg P_2O_5 ha^{-1} (Kadam *et al.,* 2014).

Table.2: Effect of different levels of phosphorous and biofertilizers on yield attributes and yield of blackgram at harvest

Treatments	Pods (Plant^{-1})	Grains (Pod^{-1})	Test weight (g 1000 seeds^{-1})	Grain yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest index (%)
Phosphorous Levels (Kg ha^{-1}) [P]							
45	26.0	5.26	32.7	841	1013	1854	45.3
60	30.7	6.30	35.8	962	1123	2084	46.1
75	32. 9	6.67	38.0	971	1191	2161	44.9
SEm±	0.9	0.21	1.0	23	31. 7	17	0.4
CD (P=0.05)	2.7	0.64	3.0	68	94.1	50	1.1
Biofertilizers [B]							
Rhizobium	32.7	6.69	36.8	968	1156	2124	45.6
PSB	30.5	6.41	36.6	962	1136	2097	45.9
Azospirillum	26.5	5.13	33.1	843	1036	1879	44.9
SEm±	0.9	0.21	1.0	23	32	17	0.4
CD (P=0.05)	2.7	0.64	3.0	68	94	50	1.1
Control	19.7	2.55	29.8	514	952	1466	35.0
P X B							
SEm±	1.6	0.37	1.7	40	55	30	0.7
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

The effect of different levels of phosphorous and biofertilizers on the economics of blackgram has been presented in Table 3. The highest cost of cultivation was recorded in the groups treated with *Rhizobium* + P_2O_5 75 Kg ha^{-1} (INR 32940 ha^{-1}) followed by PSB + P_2O_5 75 Kg ha^{-1} (INR 32910 ha^{-1}) and T10-*Azospirillum* + P_2O_5 75 Kg ha^{-1} (INR 32888 ha^{-1}), whereas lowest in the absolute control group (INR 29931 ha^{-1}). The reason may perhaps be because of the cost of phosphorus fertilizer and the biofertilizer involved in respective treatments. The gross return was recorded in the groups administered *Rhizobium* + P_2O_5 75 Kg ha^{-1} (INR 107397 ha^{-1}) followed by PSB + P_2O_5 75 Kg ha^{-1} (INR 105832 ha^{-1}) and *Rhizobium* + P_2O_5 60 Kgha^{-1} (INR 104894 ha^{-1}), whereas lowest in the absolute control group (INR 57669 ha^{-1}). The reason may perhaps be because of the grain and stover yield obtained in the respective treatments. The net return

was recorded in the groups administered *Rhizobium* + P_2O_5 75 Kg ha^{-1} (INR 74457 ha^{-1}) followed by PSB + P_2O_5 75 Kg ha^{-1} (INR 72922 ha^{-1}) and *Rhizobium* + P_2O_5 60 $Kgha^{-1}$ (INR 72535 ha^{-1}), whereas lowest in the absolute control group (INR 27738 ha^{-1}). The reason may perhaps be because of the difference in gross return and cost of cultivation in the respective treatments. The benefit-to-cost ratio (B-C ratio) was recorded in the groups administered *Rhizobium* + P_2O_5 75 Kg ha^{-1} (INR 2.26 INR^{-1}) followed by *Rhizobium* + P_2O_5 60 Kg ha^{-1} (INR 2.24 INR^{-1}) and PSB + P_2O_5 60 Kg ha^{-1} (INR 2.23 INR^{-1}), whereas lowest in the absolute Control group (INR 0.92 INR^{-1}). The reason may perhaps be because of the difference in gross return and cost of cultivation in the respective treatments. Present findings verified the results of Kumar *et al.,* (2021) who reported that the application of P_2O_5 at 60 kg ha^{-1} resulted in a significant increase in all the economical attributes over 30 kg P_2O_5 kg ha^{-1}. The interaction effect of fertility levels and biofertilizers significantly influenced the yield and economics of blackgram maximum being with 100% RDF and Rhizobium +PSB combination (Jangir *et al.,* 2016).

Table 3: Effect of different levels of phosphorous and biofertilizers on the economics of blackgram at harvest.

Treatments	Cost of Cultivation (INR ha^{-1})	Gross return (INR ha^{-1})	Net return (INR ha^{-1})	B-C Ratio
Control	29931	57669	27738	0.92
Rhizobium +P_2O_5 45 $Kgha^{-1}$	31769	90720	58951	1.85
PSB+ P_2O_5 45 $Kgha^{-1}$	31739	90114	58375	1.83
Azospirillum + P_2O_5 45 $Kgha^{-1}$	31717	82627	50911	1.60
Rhizobium + P_2O_5 60 $Kgha^{-1}$	32359	104894	72535	2.24
PSB + P_2O_5 60 $Kgha^{-1}$	32329	104580	72251	2.23
Azospirillum + P_2O_5 60 $Kgha^{-1}$	32307	90604	58297	1.80
Rhizobium + P_2O_5 75 $Kgha^{-1}$	32940	107397	74457	2.26
PSB + P_2O_5 75 $Kgha^{-1}$	32910	105832	72922	2.21
T10-*Azospirillum* + P_2O_5 75 $Kgha^{-1}$	32888	91688	58800	1.78

Conclusion

Based on the results of the present investigation it can be suggested that the application of 60 kg of P_2O_5 ha^{-1} and *Rhizobium* as seed treatment will significantly influence the growth contributing characters viz., plant height, number of branches, leaf area, number of nodules, dry matter accumulations. The highest yield and yield attributing characters viz., number of pods, number of seeds, test weight, grain yield stover yield, and biological yield were recorded with the application of 60 kg of P_2O_5 ha^{-1} and *Rhizobium* as a seed treatment. Cost of cultivation, Gross monetary returns, net monetary returns, and B: C ratio were maximum with the application of 60 kg of P_2O_5 ha^{-1} and *Rhizobium* as a seed treatment.

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Empowering rural women through life skills intervention

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Abstract

With the assumption that developing certain life skills can bring empowerment in women, an intervention study was carried out on women of Varanasi. Pre-test Post-test quasi-experimental research design was used in the study, where the sample comprised eighteen rural women. The life skills intervention (13 sessions) was done for selected ten life skills. Life Skills Inventory for Women was used for pre-test and post-test assessments, to check the level of life skills before and after the intervention. Mean, standard deviation, and t-tests were used for data analysis. The findings of the study indicated that all the participants differed significantly in life skills levels after the intervention. The level of life skills increased in the case of rural women; therefore, it can be concluded that the intervention programme-life skills module was found effective for them. The findings provide a foundation for designing a course/programme to facilitate the development of life skills among rural women.

Key words: Gender Equality, Life Skills Education, Life Skills Intervention, Life Skills Module, Life Skills, Rural Women, Women Empowerment

Introduction

Recently, the World Economic Forum published the Global Gender Report, (2017), stating that, although women represent half of the world's population, they do not have access to the same level of health assistance, education, economic participation, potential earning and political decision-making power.

Gender discrimination, female infanticide, child marriage, dowry system, patriarchal order and the subordinate status of women, illiteracy, financial constraints, professional inequality, workplace harassment, inequality in sharing the burden of household work, lack of health care and safety, violence against women, decreased self-esteem and identifying abilities and potential, lack of proper educational programme are some obstacles that go against the way of women empowerment in India.

Women empowerment is a process to make women progressive, educated, financially independent, and having good health and status. It further refers to increasing and improving the social, economic, political, and legal strength of the women by assessing their abilities/skills, making them recognize their worth, helping in boosting their confidence level, educating them about their rights, aiding them to be able to take wise decisions and solve their problems independently and survive in all adverse situations without being exploited. It would create awareness and provide the proper direction to women.

The various types of empowerments can be measured by applying the indicators in the study of women's empowerment. Qualitative Indicators of Empowerment include becoming more stronger and self-confident, increasing positive self-image, self-awareness and self-esteem, having critical thinking power and problem-solving ability, having access to information and resources for taking proper decisions on their own, having a range of options from which they can

make choices (not just yes/no, either/or), maintaining a positive relationships with others, having good communication skills and negotiation skills, developing good coping strategies to handle stress and emotions, increase in personal leisure time and time for child care, ability to learn skills for improving one's personal or group power, learning different self-defence techniques, increasing awareness about legal rights, changes in the roles and responsibilities in the family and in society, change in perspective of customs that are against anti-women, e.g. child marriage, dowry, widow marriage, etc., ability to change others' perceptions by democratic means, involving in the formation of cohesive group and development of leadership quality, and able to access information on the internet and become tech savvy. Quantitative Indicators of Empowerment include the average age at marriage, sex ratio, improvement in female literacy rate, changes in physical health status and nutritional levels, reduction in rate of violence against women, participation levels of women in the political process, and participation levels of women in different development programmes.

United Nations International Children's Emergency Fund (UNICEF) defined it as "Life Skills Education is a structured programme of needs- and outcomes-based participatory learning that aims to increase positive and adaptive behaviour by assisting individuals to develop and practice psycho-social skills that minimize risk factors and maximize protective factors. Life Skills Education programmes are theory- and evidenced-based, learner-focused, delivered by competent facilitators, and appropriately evaluated to ensure continuous improvement of documented results" (Definition of Terms, UNICEF).

A skill is a learned ability to do something well. So Life skills are the abilities that individuals have to develop to live a fruitful life. Life skills are psychosocial abilities that enable individuals to translate knowledge, attitudes, and values regarding their concerns into well-informed and healthy behaviours. World Health Organization, (1997) defines Life Skills as "*the abilities for adaptive and positive behaviour that enable the individuals to deal effectively with the demands and challenges of everyday life*". Here 'adaptive' means that a person is flexible in approach and is able to adjust in different circumstances and 'positive behaviour' implies that a person is forward looking and even in challenging situations, can find a ray of hope. United Nations International Children's Emergency Fund (UNICEF) defines Life Skills as "*a behaviour change or behaviour development approach designed to address a balance of three areas: Knowledge, Attitudes, and Skill.*

To develop healthy human beings in the world, World Health Organization (WHO) in1997 has identified ten skills that help the person to develop into a healthy responsible and productive citizen. The ten core Life skills are- Self Awareness, Empathy, Critical Thinking, Creative Thinking, Decision Making, Problem Solving, Effective Communication, Interpersonal Relationships, Coping with Stress and Managing Emotions.

Life Skills include psychosocial competencies and interpersonal skills that help people make informed decisions, solve problems, increase self-awareness, promote positive attitudes, think critically and creatively, communicate effectively, build healthy relationships, promote greater sociability, empathize with others, and manage their lives healthily and productively by preventing negative and high-risk behaviours.

Strengthening of women s' mental, emotional, and social skills is needed for empowerment. Knowing one's strengths and weaknesses is very essential for the development of an individual; it would help in deciding their life goals. Thinking skills enable women to think clearly and

rationally, take the right decision about their careers, and handle problems and conflicts in their life satisfactorily without any stress. Intense stress and emotions can have negative effects on mental health which can be reduced by Emotional skills as these skills inculcate healthy and positive coping strategies to manage stress and emotions of life. Social skills provide them with skills to maintain healthy relations with others, effective communication to put their views and to advocate for their rights and stand in society on their own. Management skills equip them to manage their healthily and productively Livelihood skills make them aware of different sources of livelihood and provide them better opportunities to earn and become independent. Safety skills teach about health care and safety, self-defence saves from violence against them.

It is important for a country that its women should be productive but it is a fact that most women are unable to utilize their potential and rights appropriately due to a lack of proper guidance and motivation. The time has challenged women in exceptional ways to find their identity, status, and value. Conditions for rural women are worse. Rural women are comparatively powerless, facing threats to their lives due to poor health, being overloaded with work, and getting less weightage and respect. They have higher illiteracy rates and earn significantly less than urban women. Rural women play a major role in supporting their households and generating income. They contribute to agriculture and rural enterprises and add to local and global economies. But due to a lack of education, decision-making skills, and problem-solving skills, they became exploited. There has been observed a lack of rural women participation in top leadership roles also. Rural women are full of potential but due to lower levels of literacy and an overload of household chores, they are unable to flourish.

Practicing life skills leads to the development of such qualities which are the foundation of empowerment requires certain skills such as self-awareness, self-esteem, effective communication, and capabilities to have the freedom to decide what to do and who to be. Adapting life skills accelerates decision-making skills, abilities that promote mental well-being and competencies to face the realities of life, enhances problem-solving skills, enables knowing their rights, negotiation, and refusal skills, improves communication skills, builds healthy relations, boosts self-esteem and self-confidence, power, improve gender relationship, awareness about health and hygiene, accessing community services and develop the ability to take responsibility for self and society. Gopikala, (2014) in the article 'Life Skills for Women Empowerment: An Overview' dealt with the empowerment of women, appropriate mechanisms and interventions have been built for the betterment and prosperity of women, and life skills are one of them. Priyadharisini and Rani, (2015) found intervention of life skills effective for women with disability in higher education in understanding their strengths and weakness so that they can easily break the personal and social bearers and lead a very self-reliant and self-dependent life.

Thus, it is essential to sensitize women towards achieving life skills for acquiring, sustaining, and preserving empowerment through the implementation of a well-planned and well-designed intervention programme. By including life skills education programs one can create awareness and provides guidance and proper direction to a woman. It aims to empower rural women by making them aware and strengthened individuals, bold enough to claim their rights, leadership, opportunities, and choices, and to participate in shaping laws, policies and programs.

Present study was conducted with objectives to assess the effectiveness of intervention programme-Life Skills

Module for developing essential life skills that leads to the empowerment among rural women.

Materials and methods

Research Hypothesis: The intervention programme would have a significant positive effect on the development of life skills among rural women which would be foster empowerment among them.

Null Hypothesis: The following null hypothesis were formed for the above objective and tested at the 0.05 level of significance.

Ho1. There will be no significant difference in pre-life skills scores and post-life skills scores

Research Design: The experimental design employed in the present study was one group pre-test- post-test design which can be symbolically presented as follows O1 X O2 Where O1 – Pre-test O2 – Post-test X - Experimentation

Methods: An experimental method (Quasi-Experimental) was employed for the study.

Population: The population of the present study comprised of all the women (rural and urban both) in the Varanasi district.

Sample and Sampling Technique: The sample comprised of eighteen rural women was selected through a convenient purposive sampling method.

Life Skills Inventory for women has included the behavioural statements related to selected ten life skills areas. Each statement describes a situation that women might have come across in everyday life. There were five choices for each statement. - Always, Often, Sometimes, Rarely, and Never. The choice selected by women suggests their level of agreement with the statement. The women responded to each item by putting a tick mark (√) and did not have an option to have any item unanswered. This tool was particularly appropriate for collecting data from the women, who are educated and comfortable in either language; Hindi or English in relatively quick and efficient manner.

Life skills module- *Life Skills for Women: An active Learning Module (LSWALM)* was developed on selected ten life skills by the investigators Dr. Poonam Tiwari & Dr. Anjali Bajpai in 2021-2022 based on a study conducted in Varanasi, UP, India. This module is designed to develop life skills among women for their empowerment. The duration of the intervention programme was of 30 hours in 13 days. The module includes ten separate sessions on ten different life skills along with a pre-session, an introductory session, and concluding session. The modules include sessions focusing on ten important life skills - Health awareness skills, Self-defence skills, Digital skills, Legal awareness skills, Self-awareness, Coping with stress, Problem-solving, Decision-making, Leadership skills, and Effective Communication skills. There were interesting, relevant and meaningful activities included in the module which were accurate, fulfill the objectives and targeted the development of life skills among rural women in the sense of empowerment.

For the sake of easy analysis, a master chart was prepared using excel spreadsheet. Mean, standard deviation, and t-test were used to arrive at meaningful inferences related to the above objective of the study.

Results and discussion

The t-test was applied to compare the pre-life skills scores and post-life skills scores of rural participants after intervention and the values obtained are shown in the table below.

Table.1: Showing comparison of the level of life skills of Pre-test and Post-test of Rural women in terms of Mean, S.D., and 't' values.

An examination of the findings in the above table reveals that the calculated t-value was 13.41, whereas the table t- value was 2.03 at 0.05 level for df=34. The calculated t-value was greater than the table t-value at 0.05 level. Hence null hypothesis was not accepted. It further reveals t-value was found to be significantly higher than the table value at

0.05 level. It can be inferred that there was a significant difference between the life skills scores of rural participants on pre-test and post-test after intervention. Further, from above table it is evident that the mean value is higher in the post-test (M=145.33) as compared to pre-test (M=86.05). This indicates that rural participants differ significantly in life skills levels after the intervention. It reveals that their level of life skills increased, therefore it can be concluded that the intervention programme-Life skills module was found effective for rural women.

Test	N	Mean	SD	t- value	Remark
Pre test	18	86.05	26.45	13.41	Significant at 0.05 level
Post test	18	145.33	10.20381		

Empowering women and enhancing their capabilities is the need of the hour. Life skills can uproot the barriers in the way of empowerment by developing certain capabilities and enhancing the hidden potential of women. Accelerating empowerment with life skills intervention can be an effective mechanism. It can be a strong strategy for empowering women. Findings of the present study reveals that there was a significant difference between the life skills scores of women on pre-test and post-test after the intervention. There was an enhancement in the level of life skills after the intervention. It indicated about the effectiveness of the intervention programme. Several studies are found supporting the findings of the present study. A study was done by Prashanthi *et al.,* (2021) concluded the need for life skills intervention program for affecting the empowerment status of farm women in Telangana. Similar findings were also obtained by Pujar and Patil, (2016) stated that the intervention of life skill education helps take positive actions and improve coping skills of stress and problem-solving ability among rural adolescent girls. Another study done by Tohani *et al.,* (2019) again stated the development of women's competence through vocational life skills education in the context of increasing the quality of the family and community socio-economy in the disaster-vulnerable village. The existence of women empowerment makes it more productive in economic activities to achieve women's welfare. Findings of the all these studies strongly provide a foundation for designing a course/programme to facilitate the development of the life skills among women. Government should focus on the need of the rural girls/women and develop policies related to their education equipped with life skills education, so that they become confident, empowered, vibrant, and productive members of the society.

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Value chain development for improving the income of cashew growers

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Abstract

Development of the Cashew Industry needs the immediate attention of the policymakers, processors, and farmers to remain competitive and profitable. There is scope to improve quality and profitability by adopting the improved method of roasting and mechanized shelling of cashew nuts. Agencies engaged in cashew processing, need financial support in the form of liberal loans with a soft rate of interest. Increasing cashew production is another important opportunity, by increasing the crop yield as well as by expanding the area under cashew plantation. About 75 percent of plantations are owned by farmers while the rest are owned by the Government. More than 50 percent of plantations are old plantations, aged between 35 to 50 years, established with seedlings of the nondescript genetic base, spaced widely, and maintained without any recommended crop husbandry practices. These plantations should be closely monitored for their performance and trees yielding less than 4-5 kg of nuts per year, should be replaced with newly grafted plants of good varieties. The spacing between the trees can also be reduced to increase the tree population. Good crop husbandry practices such as improving soil productivity and moisture content and efficient management of nutrients, pests, and diseases should be promoted by Agricultural Extension Agencies to increase the yield of nuts. There is good scope to promote cashew cultivation along the seacoast as a profitable cash crop. Suitable schemes should be developed to enable small farmers and absentee landowners to establish cashew plantations on unproductive lands. To provide timely support to small farmers and to improve their production, the value chain can play a significant role. With efficient backward and forward linkages and an increase in RCN yield, cashew can be more profitable than many other crops, including mango and other plantation crops. This will also help India to restore its leadership in cashew.

Keywords: Cashew kernel, Cashew nut, Commercial, Economics, Industries, Products.

Introduction

Cashew nut is a high value, delicious and luxury food, consumed by the affluent class in most of the countries in the world. With regard to popularity and price, cashew nut can compare well with pecans and macadamia, recording a growth of 60 per cent in demand during the last 10 years. Cashew kernel along with Basmati rice, spices and tea, are the top four agricultural exports in India. In 2017, India earned a foreign exchange of Rs. 52.13 billion, through cashew export. Cashew industry has been providing income to 7.5 million rural families under farming and 0.3 million families for processing. However, the industry in India is not in a position to encash the global opportunity of maximising the profitability, due to several challenges such as small and scattered plantations established on poor soils, inadequate investment on crop production, and absence of technical guidance and lack of efficient processing facilities. Like many other agricultural commodities, farmers are deprived of backward and forward linkages to enhance their production and profitability.

Commercial importance of cashew

Cashew is native to North-East Brazil. It was introduced in India by the Portuguese between 1563 and 1570 when they brought cashew to Goa. Later, it was introduced across the western region of the country. In the 19th century, it was introduced in other countries in Asia and Africa. Presently, cashew is cultivated in 32 countries located in the tropics, between 25°N and 25°S, with a preference for low lands, along the sea coast. Cashew grows into a tree up to a height of 14 metres (m), with a wide canopy. However, cashew trees generally attain a height of 9-12 m in widely spaced plantations, with a canopy diameter of 6-8 m, which is ideal for inducing heavy flowering and easy harvesting. Cashew is well adapted to high rainfall above 1000 mm, with a preference for temperature ranging between 19° C and 35°C, with an average monthly temperature of 25° C. Being a tropical tree, cashew requires warm and humid climate and can tolerate temperature up to 45°C (Kumar *et al.,* 2012). However, it is sensitive to low temperature and frost. Trees necessitate at least 6 hours of sunlight every day for a better performance.

Cashew trees start yielding fruits after 3-4 years but grafted plants start bearing from the second year itself. A mature tree produces about 7–12 kg nuts per year and continues to yield economically for 50-60 years. Cashew fruit consists of oval shaped colourful false fruit, in attractive red and yellow colours, developed from the receptacle of the flower, known as cashew apple with the nut attached at the tip. Ripe cashew apple is sweet and juicy, with a very short shelf life, and is consumed directly or processed into juice, squash or alcohol. However, cashew apple is wasted in most of the growing areas, due to lack of infrastructure for storage and processing.

Cashew products of economic importance

The products of cashew fruit are cashew apple and nut. Raw cashew nut (RCN), removed from ripe fruit is separated into kernel and shell. The shell is crushed, to extract a liquid, known as Cashew Nut Shell Liquid (CNSL) which contains phenolic compounds, used in the paint industry. RCN yields 20-24 per cent kernel and 20 per cent CNSL, which are traded in the international market. Cashew kernel is found inside the nut, covered by a thin membrane known as testa, which contains a non-edible substance like tannin, which protects the kernel from damage. Cashew plant parts also have several uses. The economic uses of different parts of cashew are presented in Table 1. Cashew kernel is a rich source of fat (46%), protein (18%), minerals such as calcium, phosphorous and iron and unsaturated fatty acids, inoleic acid, in particular. It is consumed directly and is also used in confectionery and bakery products. Cashew apple is a rich source of vitamin C (262 mg/100 mi juice, which is five times higher than orange juice), calcium and iron. The nutritive value of cashew kernel and cashew apple is presented in Table 2.

Cashew tree bark, leaves and gum are generally used for treating toothache and sore gums. A paste made by grinding the bark with water, is used for curing ringworm. Root extract, by boiling in water is used as a purgative. Fibre from leaves is used to treat calcium deficiency and intestinal colic. Water resistant wood is used for boats, furies and as farm tools. Resin from wood is also used as a cough remedy and insect repellent (Anonymous, 2013). Cashew leaves are also used in traditional medicine to treat venereal diseases. Cashew seed extract stimulates blood sugar absorption by muscle cells, resulting in regulating blood sugar level and preventing insulin resistance in diabetic patients. Cashew nuts also contain anti-oxidising properties, due to presence of phenolic compounds and ascorbic acid. Extracts from bark, stem and leaves can be used for treating gastro-intestinal diseases. Cashew extracts can also be used for treating, impotence, leishmaniasis,

scrofula, swelling and pain (Okpala, 2014). CNSL, extracted from roasted or boiled raw cashew nut, yields up to 25 per cent dark brown viscous phenolic liquid, which is used for producing fuel, in paints, lubricants, varnishes, as brake fluid, clutch linings, fungicides, insecticides, agglutinants and lacquers.

Table 1: Uses of different parts of cashew tree

Sl. No.	Tree Part	Products Prepared	Uses
1	Root	Water extract	Excellent purgative
2	Wood	Charcoal, Tool handles	Fuel, Packing and utility items
3	Bark	Water extract	Dyeing fishing nets
4	Bark sap	Gum	Used for indelible ink and gum for book binding
5	Leaves	Fresh leaves Dried leaves	For medicines and flowering rice For fuel and for producing Farm yard manure
6	Cashew Apple	Fruit, Juice, *feni*, syrup, jam, jelly, chutney	Fresh fruit consumed directly and fed to livestock fresh or after extracting juice. Juice is taken for controlling diarrhea, dysentery, cholera, as anesthetic in leprosy. Syrup, jam, jelly and chutney are delicious food products.
7	Cashew nut shell liquid	Phenol	Waterproof coating for cement and brick flooring, preparation of printing ink and varnishes, smearing native canoes and for medicines
8.	Testa	Powder	Used in leather industry and for poultry feed
9	Kernel	Nut and powder	Cashew milk and nuts used against loss of appetite, depression, scurvy, anemia, diabetes. Kernels consumed raw or roasted.

Source: ***Srivastava and Srivastava, 2018***

Table 2: Nutritive values of cashew kernel and cashew apple

Constituents	Kernel (%)	Apple (%)
Moisture	6.9	87.9
Protein	21.0	0.2
Fat	47.0	0.1
Carbohydrates	22.0	11.6
Fibre	1.3	0.9
Minerals	2.4	0.2
Phosphorous	0.45	0.01
Calcium	0.55	0.01
Iron (mg/100 gm)	5	0.2
Carotene (I.U/100 gm)	100	-
Vitamin B1 (mg/100 gm)	630	-
Riboflavin (mg/100 gm)	190	0.5
Vitamin C (mg/100 gm)	-	170-350

Source: ***Kumar et al., 2014.***

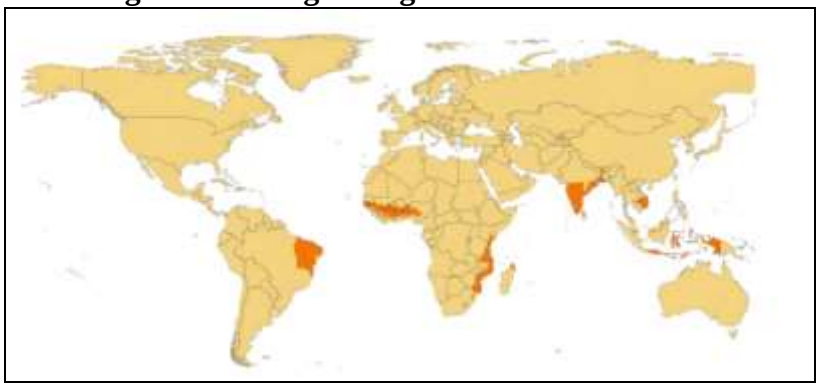
In most of the cashew producing countries, only cashew nut is processed while a small quantity of cashew apple is consumed directly. In West Africa, cashew wine is a popular alcoholic drink. In Goa, India, fermented cashew apple juice is distilled to produce a liquor, locally known as *feni*. In Brazil, the juice is used for preparing soft and alcoholic drinks.

World cashew production

Figure 1 presents the major cashew growing countries in the world. Important

cashew production regions are South Eastern Asia, West Africa, East Africa and Brazil. Important countries growing cashew are India, Vietnam, Ivory Coast, Tanzania, Guinea-Bissau, Benin and Brazil. In 2017, the total area under cashew plantation was 5.985 million ha, with the highest area of 1.676 million ha in Ivory Coast, followed by 0.978 million ha in India and 0.549 million ha in Tanzania. Vietnam has expanded the cultivation during the last 2-3 decades to bring 0.284 million ha of its land under cashew plantation.

Fig. 1. Cashew growing countries in the world



Source: ***INC, 2015***

With good crop husbandry practices, Vietnam has achieved higher RCN yield of 3042 kg per ha, as against the world yield of 663.5 kg/ ha. This has enabled Vietnam to secure first rank in world cashew nut production, with the total production of 0.863 million tonnes of RCN, as presented in Table 3. This is a significant change in the world cashew nut production scenario, as in 2012-13, Vietnam was in the third position, sharing only 9.26 per cent of the world cashew production, next to West Africa and India, who shared 33.37 per cent and 27.68 per cent of the production respectively (Anonymous, 2018). Philippines has recorded the highest yield of 7773 kg/ha, 10 times higher than the average yield in India. Average Indian cashew nut yield in 2017 was 762 kg/ha, only about 15 per cent higher than the world average, and mere 25 per cent of the average yield of Vietnam. The world RCN production in 2017 was 3.97 million tonnes, while India shared 19 per cent of the world production, next to Vietnam, as presented in Table 3 (INC, 2018).

Processing of RCN is the key commercial activity of the cashew industry, which is mainly confined to India, Vietnam and Brazil. India and Vietnam are the major cashew nut exporters sharing 73 per cent of the world trade. These countries imported RCN from Western and Eastern Africa. During 2016-17, world cashew kernel production was 0.784 million tonnes. Out of this, 0.496 million tonnes were exported to various countries, while India used 0.302 million tonnes of kernels for local consumption. Among the importers of cashew kernel, USA was the largest importer with 0.147 million tonnes, followed by Netherlands (50,347 kg), Germany (47,397 kg), UK (21,395 kg) and Australia (16,704 kg). Vietnam began importing raw cashew nuts from Africa in 1996. After 20 years, in 2015, Vietnam imported 1.1 million tonnes of the total world import of 3 million tonnes of RCN. In 2016, Vietnam exported 0.347 million tonnes of cashew kernel valued at USD 2.84 billion to over 100 countries and surpassed India to become the largest cashew kernel exporter in the world (Anonymous, 2018).

Table 3: Major cashew growing countries with area, yield and production in 2017

Rank in Prodn.	Country	Area Million ha	Yield Kg/ha	Production RCN (tonnes)	% of Total Production
1	Vietnam	0.284	3041.2	863,060	21.73
2	India	0.978	761.8	745,000	18.76
3	Ivory Coast	1.676	424.2	711,000	17.90
4	Philippines	0.029	7772.6	222,541	5.60
5	Tanzania	0.549	299.0	164,245	4.14
6	Guinea-Bissau	0.277	1166.7	155,953	3.93
7	Benin	0.456	333.2	151,836	3.82
8	Mozambique	0.167	833.7	139,000	3.50
9	Brazil	0.488	273.2	133,465	3.36
10	Indonesia	0.511	257.6	131,685	3.32
	Total world	**5.985**	**663.5**	**3,971,046**	**100.00**

Source: ***INC, 2018***

Indian leadership in cashew industry

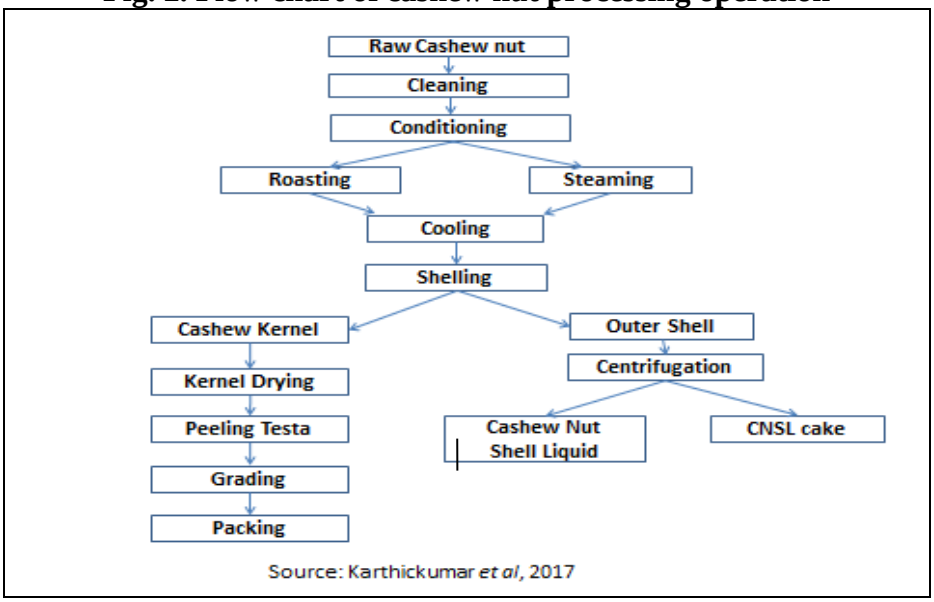
Cashew was initially promoted in India primarily for control of soil erosion along the sea coast in Goa during the 16th century and subsequently along the West and East coasts for nut production. India was the world leader in cashew production, processing and export marketing, with over 45 percent of the global production, for many decades. However, with the entry of other countries, India is now the second largest producer, sharing only 18.8 per cent of the world production after Vietnam, as presented in Table 3. With regard to the area under cashew plantation, India with 16.34 per cent of the world area, stands next to Ivory Coast, who own 28 per cent of the plantation area. With regard to yield of RCN, India is in 5th position, after Philippines, Vietnam, Guinea-Bissau and Mozambique (Table 3). Among the top cashew kernel exporting countries also, India stands second and is now maintaining its first rank only with respect to consumption of cashew nut. This scenario strongly reflects on the lack of organized efforts to optimize the production and profitability and calls for in-depth analysis of the on-going practices and adoption of a suitable strategy to regain supremacy.

Cashew nut processing method

Separation of cashew kernel without breaking from the nut is the most important part of cashew processing. This is because pricing of cashew kernels is based on the colour and size. The processing is done by different methods. Traditionally, the nuts were processed manually but since 1960s, mechanization has been introduced for roasting, shelling and CNSL extraction. The flow diagram of processing is presented in Figure 2. The process starts with cleaning of nuts to make it free from sand, dried apple and other foreign matter. The nuts are then soaked in water, while changing the water 2-3 times, to increase the moisture content in the shell to 9 per cent. To make the shell brittle, the nut is either roasted in an open pan or closed drum or steamed. In this process, CNSL is also released. Steam roasting is the improved method, where uniform cooking takes place and CNSL is collected separately. The roasted cashew nut is dried on the floor before shelling either manually or by using mechanical devices. Centrifugal shelling machine is an efficient device, which requires the nuts to be graded before shelling, as it operates at different speeds based on the size of the nut. The kernel is separated from the shell and pre-grading is done by separating unbroken kernels. These kernels covered with brown testa are dried to reduce the moisture content from 6 per cent to 3 per cent, either by sun drying or by using dryers. This is followed by peeling of testa, either manually or by mechanical peelers. After peeling of testa, the kernels are graded on the basis of colour and size.

Table 4 presents the grades and classes of cashew kernel, based on the colour and sizes. These graded kernels are packed in different quantities, generally in 25 pounds, in air tight tin containers, using 'vita pack' process. This involves removal of air from the container and replacing with carbon dioxide, thereby maintaining the kernels in good condition.

Fig. 2. Flow chart of cashew nut processing operation



Cashew business development

India has been the leader in export of cashew kernel since the 1950s. Although cashew was introduced along the sea coast for soil conservation in the 16th century, commercial cashew processing in India was first started as a cottage industry under the name of Indian Nut Company in 1920s by a Sri Lankan entrepreneur, Roch Victoria, who migrated to Kollam in Kerala. With the increasing demand for processed cashew kernel, others also established processing facilities and by 1939, the export of cashew kernel increased to 1350 tonnes. However, World War II brought a complete halt to cashew trade. Later, cashew export picked up in mid-1950s, after the introduction of airtight tins infused with carbon dioxide, for extending its keeping quality. Subsequently, as the export demand increased, new cashew processing plants were established outside Kerala, in Mangalore and Goa. To address the problem of international raw cashew importers, who started indulging in unfair trade practices, the Indian business leaders in cashew processing, formed a Cashew Syndicate, which also started purchasing RCN from the growers at pre-determined prices. To formalise this initiative, the Cashew Export Promotion Council (CEPC) was established in 1955, under the Commerce Ministry.

Table 4: Grades of cashew kernels based on size and colour

A. Classification based on colour of kernel		
Class	**Commercial designation**	**Description**
Extra	White	White, pale, ivory, pale, ash-grey, light yellow
Class I	Scorched or Lightly blemished	Light brown, light ivory, light ash-grey, deep ivory, yellow
Class II	Scorched seconds	Light brown, amber, light blue, deep brown, deep blue,

	or Dessert	discoloured, black spotted, immature, blemished and stained kernels

B. Grades based on size of kernel		
Standard Grades	**Maximum No. of Kernels / pound**	**Maximum No. of Kernels/ kg**
W150	150	325
W180	180	395
W210	210	465
W240	240	530
W320	320	706
W450	450	990
W500	500	1100

Source: ***Gupta, 2018***

In 1969, the Government of Kerala established the Kerala State Cashew Development Corporation (KSCDC) mainly to protect the interest of workers engaged in the industry. CEPC promoted cashew processing in all the other states where cashew was cultivated. Thus, many cashew processing units were established under the cottage industry in Kerala, Karnataka, Goa, Maharashtra, Andhra Pradesh and Tamil Nadu. In Kollam district in Kerala alone, there were over 600 cashew processing units (CEPCI, 2018). In 2016, there were 3940 cashew processing units across the country with a capacity to process 1.64 million tonnes of RCN, with an average installed capacity of 400 kg. The majority of the processing units were in Maharashtra (55.8%). However, the highest installed capacity was in Kerala (36.5%), followed by Tamil Nadu and Karnataka, as presented in Table 5. Out of these, about 60 per cent were automatic or semi-automatic units, while the rest were manual units which were very inefficient with higher rate of damaged kernels. However, as these units had made capital investments and obligation of engaging their workers, processing activity continued as long as the business was viable.

During the year 2008-09, the RCN production in India was 0.613 million tonnes, which was only about 50 per cent of the requirement by the cashew processing units. To meet the shortfall, 0.606 million tonnes of RCN was imported from Africa (Chandrasekaran and Jeyakumar, 2014). The import of RCN during the next 8 years till 2016-17 is presented in Table 6. With growing import of RCN and competition by other countries, Indian cashew processing Industry started feeling the pressure. Due to the increasing cost of imported RCN and high labour cost contributed by inefficient processing units, many processing units were running at a loss. Out of 840 processing units in Kollam, 80 per cent had closed down, making 0.35 million people, mainly women, jobless. Hence, the challenge was to revive the viable units through modernisation and improve the skills of the labour engaged in these units to work efficiently.

Table 5: State wise share of processing units and installed capacity in India in 2017

State	**Processing Units (No.)**	**Share of Processing Units (%)**	**Installed Capacity (000 tonnes)**	**% Share of Installed Capacity**	**Average Installed Capacity (Tonnes)**
Kerala	432	11.0	600	36.5	1.4
Karnataka	266	6.8	300	18.3	1.1
Goa	45	1.1	50	3.0	1.1

Maharashtra	2200	55.8	50	3.0	0.0
Tamil Nadu	417	10.6	400	24.3	1.0
Andhra Pradesh	175	4.4	100	6.1	0.6
Odisha	350	8.9	120	7.3	0.3
West Bengal	30	0.8	8	0.5	0.3
Chhattisgarh	3	0.1	5	0.3	1.7
N E States	22	0.6	10	0.6	0.5
Total	**3940**	**100**	**1643**	**100**	**0.4**

Source: ***SFAC, 2018***

In 2006-07, India imported 0.593 million tonnes of RCN valued at Rs.18.116 billion, inspite of the introduction of import duty of 9.4 per cent during that year. There was a steady increase in the import until 2016, when price of RCN increased from USD 800 to USD 1800 per tonne. As the competitors in Vietnam and China were more efficient, the Indian Cashew Industry with increasing procurement cost and tax, could not maintain the profit margin and hence, started reducing the operation. The RCN import which was 0.96 million tonnes in 2015-16, had reduced to 0.65 million tonnes in 2017-18. The problem is likely to aggravate further as major African cashew growing countries are preparing to process at least 50 per cent of the produce locally. As 75 per cent of the Indian import of RCN was from Western Africa and 24 per cent from Eastern Africa (INC, 2018), the pressure on price rise is likely to continue further. It can be observed from Table 6 that Indian cashew import bill has been significantly higher than the export bill since 2011-12, because of higher price of RCN and increasing domestic consumption of cashew kernel. This indicates a bleak future for the cashew industry, unless suitable measures are taken to keep the business competitive and profitable. Hence, it is necessary to improve the yields of Indian cashew plantations and processing facilities on priority.

Table 6: Import of raw cashew nut and export of cashew kernel and cashew shell liquid in India from 2006-07 to 2016-17

Year	RCN Import		Cashew Kernel Export		Cashew Shell Liquid Export	
	Quantity (MT)	Value Rs. Billion	Quantity (MT)	Value Rs. Bill.	Quantity (Tonnes)	Value Rs. Mil.
2006-07	0.593	18.116	0.119	24.552	6139	102.9
2007-08	0.606	17.468	0.114	22.890	7813	119.8
2008-09	0.606	26.324	0.110	29.884	9099	260.6
2009-10	0.756	30.475	0.118	28.016	11227	276.2
2010-11	0.529	26.496	0.106	28.194	12051	337.7
2011-12	0.809	53.378	0.132	43.907	13575	594.6
2012-13	0.892	53.311	0.100	40.672	9192	298.4
2013-14	0.771	45.640	0.115	50.587	9480	306.1
2014-15	0.940	65.709	0.119	54.329	10938	558.1
2015-16	0.958	85.610	0.096	49.521	11677	575.9
2016-17	0.770	88.394	0.082	51.688	11422	440.0

Source: ***Nayak and Paled, 2018***

Cashew production in India

After independence, agricultural development for food security was given high priority, but cashew development did not draw any attention, till the

implementation of the 2nd National Five-year Plan during 1956–61. Under this Plan, it was proposed to increase the production of RCN from 60,000 tonnes to 80,000 tonnes in 1961, by expanding the area under cashew cultivation on the east and west coasts, in the states of Karnataka, Maharashtra, Andhra Pradesh, Odisha, West Bengal and Andamans, and to introduce in the central part of India (Planning Commission, 2012). In 1966, when the total area under cashew plantation was 0.24 million ha, producing 0.1 million tonne RCN per annum, with an average yield of 400 kg RCN/ha, the Government of India established the Directorate of Cashew nut Development with a mandate to boost cashew production. Over the next three decades, the Directorate initiated various activities to increase the area by three times and production by four times, with an annual growth of 4 per cent. Several State Governments led by the Government of Kerala, established the State Cashew Development Corporations to boost the cashew industry. State Forest Departments were directed to establish cashew on the forest and other Government lands along the sea coasts. Later, these plantations were transferred to newly formed corporations under the respective State Forest Departments. In all, about 26 per cent of the cashew plantations were on public lands. Farmers having barren lands along the sea coast and adjoining hilly terrains were also motivated to establish cashew, without any serious business plan. It can be observed from Table 7 that the area under cashew production was 0.464 million ha in 1980-81 which gradually increased to 1.04 million ha over 35 years. The yield of RCN also doubled during the same period, resulting in 416 per cent increase in total production as shown in Table 7. However, this yield is far below, Philippines and Vietnam.

Table 7: Area, production and yield of cashew in India

Year	Area Million Ha	Production Million tonnes	Yield Kg/ Ha
1980-81	0.464	0.185	399
1985-86	0.522	0.234	324
1990-91	0.532	0.295	555
1995-96	0.635	0.418	658
2000-01	0.720	0.450	625
2005-06	0.837	0.573	685
2010-11	0.945	0.653	653
2015-16	1.037	0.671	647
2016-17	1.041	0.779	762
2017-18	1.062	0.817	769

Source: ***Nayak and Paled, 2018***

Table 8 presents the state-wise status of cashew production in India. Out of 1.041 million ha in 2016-17, Maharashtra, Andhra Pradesh and Odisha, each shared around 18 per cent of the plantation area, while Tamil Nadu, Karnataka, Kerala and Goa shared 13.6, 12.3, 8.7 and 5.6 per cent areas respectively. Chhattisgarh, West Bengal and Gujarat have significantly lower area under cashew. With regard to cashew nut yield, Maharashtra topped with 1378 kg per ha, followed by West Bengal. The yield in other states ranged between 393 kg and 1140 kg, as against the national average of 762 kg per ha. It is a matter of concern that the average yield is significantly low in Andhra Pradesh, Odisha, Tamil Nadu and Karnataka, which are among the top five states with respect to area under plantation, thereby bringing

down the total national production of RCN. Out of the total RCN production in the country, 33 per cent was contributed by Maharashtra, while Andhra Pradesh and Odisha contributed only 14 per cent and 12 per cent respectively, inspite of having similar acreage.

Economics of cashew production

Establishment of cashew plantations on under-utilised lands, particularly along the sea coast can be an excellent strategy to generate income for the local communities, prevent soil erosion and enrich the bio-diversity. There are vast stretches of idle lands along the sea coast and village forests which can be used for establishing cashew plantations. Cashew can be established with or without irrigation facilities, where the rainfall is above 750 mm per annum.

In Tamil Nadu, the average cost of establishing a new cashew plantation on coastal sandy lands was Rs. 8500 per hectare in early 2010s. Providing irrigation facilities, wherever water sources were available, cost an additional Rs. 1800. The plant population maintained in irrigated plantation was 169 while it was only 146 plants under rain fed conditions. The cost of various inputs for establishing cashew plantation is presented in Table 9. The average cost of establishing cashew plantation was around Rs. 10,000 of which 32.7 per cent was on manure and fertilizers, 23.3 per cent on land development, 11 per cent on weeding, 9 per cent on planting and 8.4 per cent on saplings (Loganathan *et al.*, 2016). The cost of establishment will be at least 3-4 times higher on hilly terrains due to high cost of land development. Hence, priority may be given to coastal lands for establishing new plantations. From the cost of planting material presented in Table 9, it seems that seedlings were generally used for planting. Use of grafted plants of high yielding variety will be desirable, although the cost of establishment will increase by Rs. 2500 - 3000 per ha.

Table 8: State-wise cashew area, production and yield in India (2016-17)

Sl. No.	States	Area 000 ha	% Share	Production 000 tonnes	% Share	Yield Kg/ha
1	Maharashtra	186.20	17.89	256.61	32.93	1378
2	Andhra Pradesh	185.57	17.83	111.39	14.29	600
3	Odisha	183.32	17.61	93.90	12.05	513
4	Tamil Nadu	141.58	13.60	67.65	8.68	478
5	Karnataka	127.86	12.28	85.15	10.93	672
6	Kerala	90.87	8.73	83.98	10.78	962
7	Goa	58.18	5.59	32.66	4.19	561
8	Jharkhand	14.83	1.42	5.83	0.75	393
9	Chhattisgarh	13.70	1.32	9.33	1.20	681
10	West Bengal	11.36	1.09	12.96	1.66	1140
11	Gujarat	7.22	0.69	6.50	0.83	900
12	Pondicherry	5.00	0.48	2.16	0.28	432
13	Tripura	4.25	0.41	3.45	0.44	812
	Others	10.95	1.05	7.77	100.00	710
	India Total	**1040.89**	**100**	**779.34**	**100**	**762**

Source: ***Nayak and Paled, 2018***

Table 9: Establishment cost of cashew plantation in coastal Tamil Nadu in first year

Sl. No.	Operations	Rain fed (Rs/ha)	Irrigated (Rs/ha.)	Average Cost in %

1	Land clearing	2002	2304	23.3
2	Digging of pits	578	610	6.6
3	Seedling and transportation	723	820	8.4
4	Planting, staking and mulching	807	785	9.0
5	Weeding	916	1150	10.9
6	Manures and fertilizers	2736	3600	32.7
7	Plant protection	263	580	3.6
8	Irrigation charges	476	520	5.5
9	Total cost	8500	10369	100.0
10	Average No. of trees/ha	146	169	150
11	Cost per tree	58	61	59

Source: ***Loganathan et al., 2016***

The annual maintenance cost of cashew plantation in Coastal Tamil Nadu during 2000 to 2010 is presented in Table 10. The present cost of maintenance will be higher atleast by 50 – 100 per cent, due to high cost of inputs and labour. However, the data suggests that the major cost is on manure and fertilizers, followed by plant protection chemicals and weeding. Harvesting will start from the fourth year in case of plantations established from seedlings and fruiting will be early by one year on grafted plants.

Table 10: Maintenance cost of cashew plantations in coastal Tamil Nadu

Sl. No.	**Operations**	**Yr. 2 Rs/ha**	**Yr.3 Rs/ha**	**Yr. 4 Rs/ha**	**Yr.5 Rs/ha**	**Yr. 6 Rs/ha**	**Yr. 7 Rs/ha**	**Yr. 8 Rs/ha**
1	Seedling and transportation	82.5	-	-	-	-	-	-
2	Planting, staking, mulching	25	-	-	-	-	-	-
3	Weeding	464	425	425	425	425	425	425
4	Manure and fertilizers	2987	3337	3700	3883	4101	4412	4701
5	Plant protection chemicals	736	913	929	1221	1386	1424	1502
6	Harvesting	-	-	104	176	225	288	385
7	Total cost	4295	4675	5157	5711	6136	6549	7013
8	Cost per tree	24	26	29	32	35	37	8

Source: ***Loganathan et al., 2016***

Considering the operations in 3 different locations namely Cuddalore, Ariyalur and Pudukkottai, the average establishment cost was Rs. 17177 for rain fed plantations and Rs. 20535 for irrigated plantations as presented in Table 11. Total annual cost was Rs.18022 and Rs. 21538 per ha for rain fed and irrigated plantations respectively. The average cost of maintaining a tree was Rs.123 under rain fed condition and Rs. 127 under irrigation. The yield of RCN under irrigation was 970 kg per ha as compared to 730 kg under rain fed conditions. This also reflected on the gross income which was Rs. 43,650 and Rs. 33,288 under irrigated and rain fed conditions respectively. The cost of production of raw cashew under rain fed condition was Rs. 24.7 while it was Rs. 22.2 per kg under irrigation. This confirms that the cost of production under irrigation is lower due to higher yield (Loganathan *et al.,* 2016). The Benefit cost ratio was 2.03 and 2.28 for rain fed and irrigated plantations respectively. The Internal Rate of Return (IRR) was 37.44 per cent and 42.05 per cent for rain fed and irrigated crops respectively.

In South Goa, the cost of establishing cashew plantation in 2017-18 was Rs. 63217 while it was Rs. 56220 in North Goa. The annual cost of cultivation was around Rs. 50000. These costs are significantly high compared to the cost in

Tamil Nadu, which can be attributed to the increase in the cost of all the inputs over the last 12 -15 years and non-availability of labour in Goa. The farmers in Goa identified non-availability of good quality planting material, shortage of water for irrigation, attack of pests and diseases and non-availability of labour as their main constraints (Mundinamani *et al.,* 2018).

Factors contributing to cashew production in India

Lack of incentives for establishing cashew plantations: The growth rate in cashew production in India has been very slow due to several reasons. These include availability of land, quality of land, investment in establishment of plantation and maintenance, cashew varieties, type of planting material, crop husbandry practices and poor extension services. There were no serious efforts by the Government to promote establishment of cashew plantations by farmers. For instance, Kerala state started implementing the Kerala Land Reforms Act, 1967 in the 1970s. Under this Act, land ceiling of 6 ha on individual land ownership was introduced, but the area under plantations was exempted, which motivated many land holders to convert their land into plantations. However, as cashew crop was not included in this list, an opportunity to expand cashew plantation was missed. The State Governments promoted many cash crops like rubber and oil palm by providing financial assistance but cashew was neglected. Ideally, cashew can be the main species for establishing greenery along the sea coast and the land owners in this region can be assisted to procure good quality grafted plants of good height to ensure low mortality and early bearing. Barren lands owned by absentee landlords, who have migrated to cities can also be brought under cashew plantation, by encouraging them to lease them out for cashew plantation, introducing suitable changes in the policy and by providing incentives.

Table 11: Costs and returns of cashew production under rain-fed and irrigated conditions

Sr. No.	Particulars	Rain-fed Rs/h	Irrigated	Overall	% of Total
	Establishment Cost	17177	20535	17878	
	Annual Fixed Cost				
1	Annual share of Establishment cost	2101	2512	2187	11.8
2	Depreciation cost	314	540	352	1.9
3	Interest on fixed capital	1268	1080	1237	6.7
4	Rental value of owned land	2307	2320	2309	12.4
5	Land cess	122	125	123	0.7
	Sub Total 1	**6112**	**6577**	**6207**	**33.4**
	Annual Variable Cost				
1	Human labour	3820	3705	3765	20.25
2	Bullock power	394	580	425	2.3
3	Machine power	819	1250	891	4.8
4	Manure and Fertilizers	4803	6229	5041	27.1
5	Plant Protection chemicals	1344	1497	1369	7.4
6	Irrigation charges	-	740	123	0.7
7	Interest on working capital	730	960	768	4.1
	Sub Total 2	**11910**	**14961**	**12383**	**66.6**
	Total cost	**18022**	**21538**	**18589**	**100.0**

1	Average no. of plants per ha	146	169	150	
2	Cost per tree	123	127	124	
3	Yield (kg/ha)	730	970	770	
4	Gross income @Rs. 45/kg	33288	43650	35035	
5	Net income	15266	22122	16446	
6	Cost of production (Rs./kg)	24.7	22.2	24.1	
7	Output – Input Ratio	1.85	2.03	1.88	

Source: ***Loganathan et al., 2016***

Aging of plantations: Age of the plantation has a significant influence on RCN yield. In 1995, out of 0.635 million ha of cashew plantation, 47.5 per cent were old, above 30 years, where the average yield was 440 kg/ha, while about 26.7 per cent area had young trees below the age of 15 years, with an average yield of 600 kg/ha, as presented in Table 12. It is essential to reestablish the old plantations with grafted plants of high yielding varieties. It can also be observed from Table 12 that 74 per cent of the total plantation area is owned by private land owners while only 26 per cent area is owned by the Forest Department and Plantation Corporations. Establishment of new, high-density plantations, by uprooting old trees will need heavy investment to the tune of Rs.75,000 to 100,000 per ha and hence, suitable schemes should be developed to provide soft credit, good quality grafted plants, irrigation facilities and technical guidance to adopt good crop husbandry practices.

Poor crop husbandry: Traditionally, cashew was never considered as a high value crop in India, as the major business was dependent on RCN imported from Africa. In the past when cashew cultivation was promoted, farmers were advised to establish the plantation more for soil and water conservation, because neither was economics of cashew plantation known nor were suitable technologies developed to boost the production. Generally, the lands used for cashew plantation in India have been either infertile sandy lands along the sea coast or heavily eroded, denuded hilly lands, unproductive and unsuitable for growing other crops. Such lands needed to be developed through field bunds and terraces for soil and water conservation and to prevent inundation of salt water in the plantation. The plantations on Government lands were also established without any land preparation for harnessing rain water and without any irrigation facilities. Most of the plantations established before 1970s, were by planting seedlings of unknown genetic sources. These factors contributed to high mortality, lower tree density, slow growth, prone to major pests like stem borer and tea mosquito, delayed fruiting and lower yield.

Table 12: Age wise yield of cashew plantations in India in 1995

Plantation Age Group	**Ownership**	**Area**		**Production**	**Yield**
		000 Ha	**% of Total**	**000 tonnes**	**Kg/Ha**
< 15 years	Private	143.50	22.60	88.00	600
	Forest / Corporation	26.00	4.09	14.00	
15- 30 years	Private	120.35	18.95	148.00	1035
	Forest / Corporation	15.80	2.49	38.00	
>30 years	Private	205.45	32.35	100.00	440
	Forest / Corporation	96.25	15.16	32.00	
Total	**Private**	**469.30**	**73.90**	**336.00**	**720**
	Forest / Corporation	**165.70**	**26.10**	**84.00**	
Grand Total		**635.00**	**100.00**	**420.00**	

Source: ***CEPC 1997***

Improved varieties and spacing: Realizing the need for scientific support to boost cashew production, the Government of India had launched the All India Coordinated Spices and Cashew improvement Project in 1971. The research received further boost with the implementation of a World Bank-aided multi-State Cashew Project in the States of Andhra Pradesh, Kerala, Karnataka and Orissa from 1982-86. A National Research Centre for Cashew was established in 1986 at Puttur in Karnataka to increase the production and productivity of cashew, with 8 research centres in 8 cashew growing states in the country. These institutions have now selected high yielding cashew varieties for different regions, as presented in Table 13. Final selection of varieties can be made on the basis of the yield per tree and size of the nut. Other recommendations such as use of grafted plants of 45- 60 cm height, produced from soft wood grafting, high density plantation by maintaining a spacing of 4 x 4 m instead of 8 x 8 m, application of recommended doses of manures and fertilizers, 1-2 irrigations at the time of fruit set, regular control on major pests, control of tree height by regular pruning, harvesting of fully ripe fruits and immediate separation and shade drying of cashew nut, etc. will certainly help in increasing the yield per tree and total production. Unfortunately, there is a wide gap between the Research Institutions, Agricultural Extension Department and farmers engaged in cashed production. This calls for a strong backward and forward networking, which has been missing to a great extent.

Table 13: Superior varieties of cashew released by various institutions in India

Institution	Cultivars	Hybrid/ selection	Year of release	Yield (kg/tree)	Nut weight (gm)
RRS, Vridhachalam, Tamil Nadu	VRI (Cw)-5	Hybrid	2007	13.2	7.2
RFRS, Vengurla, Maharashtra	Vengurla-2 Vengurla-7	Selection Hybrid	1979 1997	24.0 18.5	4.3 10.0
ARC, Mangalore, Karnataka	Ullal-2 Ullal-4	Selection Selection	1984 1994	14.7 10.5	6.0 7.2
NRC, Puttur, Karnataka	NRCC-sel-2 Bhaskara	Selection Selection	1989 2005	9.0 18.5	9.2 6.5
ARS, Chintamani, Karnataka	Chintamani-2	Selection	2007	29.8	7.9
CRS, Bapatla, Andhra Pradesh	BPP-8 Jagannath	Hybrid Hybrid	1989 2008	14.5 10.5	8.2 8.6
CRS, Annkkayam & Madakkathara, Kerala	Kanaka Priyanka	Hybrid Hybrid	1993 1995	19.0 16.9	6.8 10.8

Source: ***Kumar et al., 2012***

Development of cashew value chain

Poor backward and forward linkages

Even though India has made significant progress in agricultural production during the last six decades, thereby raising food grain production from 50 million tonnes in 1950 to 277.5 million tonnes in 2017-18, marketing of the produce has been the weakest link in agricultural development, which has heavily influenced the profitability of farmers. Realising the difficulties faced by the farmers in marketing their produce, the Government of India assured minimum support price for major food grains and even established procurement centres for a few important

crops, where farmers could not sell their surplus produce in local markets. In the absence of a fair and efficient marketing system, neither the farmers can obtain a fair deal nor can the country boost its agricultural production. This holds good for cashew as well. Fortunately, the cashew industry in India started with processing and marketing. However, the production segment has been completely neglected.

Value chain is a network where all the stakeholders associated with the crop or commodity, share a common platform and interact with each other with a goal of optimising the production and value addition. These are the intermediaries between the farmers and consumers. They include scientists, extension experts, development agencies and farmers' organisations, input producers and distributors, financial institutions and insurance agencies, traders, warehouse owners, transporters, processing establishments and marketing organisations. Local farmers' cooperatives, dedicated civil society organisations or Producer Companies can take the lead in coordinating the value chain platform, as value chain has to primarily protect the interest of farmers.

For effective functioning and inclusion of small farmers, producers' groups of 100 - 500 farmers or even more, preferably belonging to a homogeneous land holding and socio-economic category, may be formed for sharing inputs, technology, infrastructure, services to promote efficient production and marketing. This calls for a committed facilitator at the village level to provide hands-on technical guidance to individual farmers, while organising input distribution, credit facilitation, development of water resources, establishment of agro-engineering services and post-harvest management of the produce such as collection, cleaning, grading, packing and transportation of the produce to various destinations. With such an organisational set up either in the form of informal or registered groups or cooperatives, even small farmers can sell all the surplus produce without any exploitation by moneylenders and middlemen. With timely availability of inputs and technical guidance, these farmers can take up production of even high value crops and increase their crop yield and income.

The other reasons for poor price realization for RCN by small farmers in India were as given below:

1. Poor quality nuts, due to small size; rancid due to improper drying
2. Change in colour of the nut, brownish instead of greenish gray colour due to excessive drying under direct sunlight,
3. Lack of storage facilities and financial crunch compel small farmers to sell their produce immediately after the harvest, when the price is the lowest;
4. In remote villages where the area under cashew plantation is small, farmers are compelled to sell RCN at a low price as local traders are reluctant to buy;
5. Many farmers are not even aware of the prevailing price of RCN in international and domestic markets and hence they end up in unfair deals.

It is clear that inspite of the leadership in international cashew export market, India has not been managing the operations efficiently. The weakness can be observed in processing, procurement of RCN from farmers and production of nuts.

Value chain for cashew nut in Odisha and Goa

Since the development of the cashew processing Industry in 1960s, the processing agencies found it easier and cheaper to import RCN from Africa than to procure it directly from local farmers, thereby making it difficult for small scale cashew producers to sell their produce at a better price. In the absence of a well-developed marketing network, the village traders collected cashew from individual households or from the village market and sold it in the larger market, around the cashew processing units. As the farmers

did not receive a remunerative price, there was no desire either to expand the area or to take good care of the plantation for increasing the production.

The processing units on the other side were not efficient, which resulted in poor quality kernel production and reduction in their profit margin. Hence, they were not willing to pay a better price. This was a vicious cycle. For instance, in Odisha, during 2004-06, there were 117 cashew processing units spread over 13 districts, with a production capacity of 11046 tonnes per annum. Most of the units followed roasting method, which was labour intensive, with poor recovery of products, and poor control on the quality of the kernels. These units were able to operate only for five months in a year, using the domestic RCN. Some of them have tried to import RCN from Africa through brokers, but the capacity utilization has been very less, causing financial loss. The processing units sold their produce through the retailors in and outside the state. They neither had their own outlets nor any brand to sell their produce. They were also unable to export due to lack of proper packing facilities. The Cashew Processors' Association has been trying to improve the processing facilities, which calls for huge investments (Srivastava and Srivastava, 2018). They are also considering the possibility of importing African cashew nut at a low price but it may be difficult, as many African countries are developing their own processing facilities. Hence, a better option is to improve the local value chain by improving the processing facilities and efficient collection of RCN from growers by avoiding middlemen at several tiers.

In another study of cashew value chain conducted in Goa during 2008-07, it was reported that the area under cashew production was gradually increasing. Odisha had the highest growth of 4.80 per cent, followed by Kerala (3.51 per cent and Karnataka (1.93 per cent). With respect to RCN production, Karnataka had the highest growth of 5.70 per cent, followed by West Bengal (2.60 per cent) and Goa (2.40 per cent). In North Goa, 50 per cent cashew farmers sold their RCN to their own Cooperative Society, 31 per cent farmers sold it to two other cooperatives, 8 per cent farmers sold it to the processing units and only 7 percent farmers sold it to village traders. In South Goa, 58 per cent growers sold their RCN to two Cooperatives, 12 per cent sold to wholesalers, 6 per cent to village traders and 4 per cent to the processing units. The involvement of middlemen was minimum. This enabled recovery of a very good price between Rs. 142 and 151 (Mundinamani *et al.,* 2018). However, such an effective cooperative marketing does not exist in many other states, thereby requiring immediate attention.

Cashew development by BAIF

BAIF Development Research Foundation is a civil society organisation, engaged in promoting sustainable livelihood for marginal and small farmers in India through livestock and agricultural-based interventions. Promotion of tree-based farming on degraded wastelands was introduced in the 1970s, which generated income and employment for tribal families, while enriching the biodiversity and environment in the region. Rehabilitation of the tribal families of south Gujarat, who owned denuded hilly lands and struggled to cultivate staple food crops like paddy, finger millet, pearl millet and some legumes, with very low yield due to poor agronomic practices, was a challenge. Tillage activities during the rainy season accelerated soil erosion and denudation of the adjoining lands. As these families could not increase crop production, they were motivated by BAIF to cultivate mango and cashew crops, and provided financial support to meet the cost of establishment of the plantation. As most of them were marginal land holders, the project was limited to establishing plantation on 0.4 ha. Mango was a popular fruit crop grown in the region and hence,

these tribal farmers were willing to grow mango. However, as the performance of mango was likely to be low in the absence of irrigation facilities, BAIF wanted to introduce a hardier crop like cashew, which was again not commonly grown in Gujarat. Hence, grafted cashew plants of Vengurla variety were established on a small scale along with mango in some of the orchards.

After 3-4 years of comparative performance in Navsari and Valsad districts of Gujarat, BAIF assessed the suitability of cashew for these hilly terrains because of its ability to tolerate drought, lower maintenance cost, regular bearing, long shelf life and steady market. Hence, cashew cultivation was promoted systematically during late 1980s. The challenge was to empower illiterate tribal farmers, who owned less than 1 ha denuded land and without any financial resources, to grow an unknown crop which can start generating income from the second year instead of waiting for 3-4 years. Cashew was not commercially grown in Gujarat and hence no technical guidance and agricultural services were available from the Government of Gujarat. Fortunately, financial support to cover the cost of establishing the plantation was assured from KfW (German Development Bank). As the objective of the programme was to provide sustainable livelihood, BAIF adopted a suitable strategy of ensuring higher production and income, adequate to sustain their livelihood (Hegde *et al.*, 2003).

Cashew value chain promoted by BAIF

Figure 3 presents the role of different stakeholders in the cashew value chain. The producer company promoted by BAIF, VAPCOL, received the fresh or processed produce, packed it well after labelling it with the brand name, collected the orders from wholesalers, retailers and large customers and dispatched the consignment accordingly. The members of VAPCOL had close coordination with the central processing unit of BAIF, which received processed cashew from the cooperative processing units, inspected the quality and further processed it wherever necessary. After verification of the quality and grades, the final product was packed as per the prescribed standard and kept ready for dispatch to VAPCOL. At every village, Gram Vikas Mandal (GVM - Village Development Committee) was promoted by BAIF, who were also the members of the Processing Cooperative. These Mandals set up seasonal cashew collection centres in every village, where cashew growers, who are the members of the Organisation, brought RCN. The Committee stored the RCN at the village collection centre and forwarded it to the processing unit, at the earliest.

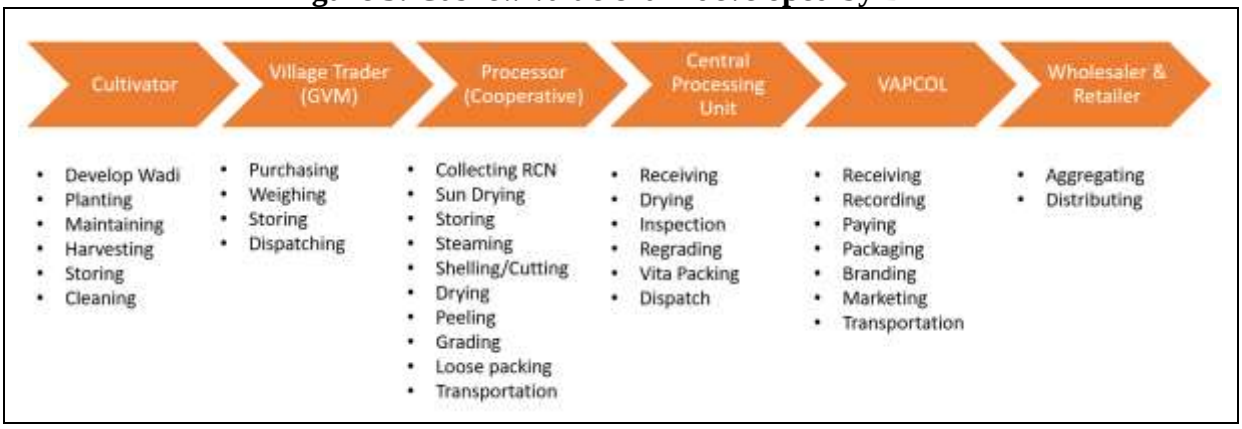
This arrangement of selling raw cashew nut was made known to every farmer through the cashew growers' groups. These farmers being first time cashew growers, were trained in nurturing cashew plants, soil and water conservation, plant protection, harvesting, timely separation of cashew nut from cashew apple, cleaning and drying of nut and use of cashew apple for direct consumption and processing for value addition. Most of the farmers brought their RCN to the GVM, as this was their own organisation and there was no alternate selling outlet either in the village or in the nearby town. However, in other cashew producing states, where cashew was grown by farmers on their own and there were no official RCN procurement centres, local traders collected cashew nut from farmers at their hamlets either by paying a very low price or exchanged it for food or other commodities of very low value. Hence, there was no incentive for small farmers to invest in inputs, required for increasing production. Even the well-to-do cashew growers sold the cashew nuts to local traders who in turn sent it to medium or larger traders in the areas where cashew processing facilities were operating. In this process, there were several intermediaries, reducing the profit share of farmers. With

the setting up of decentralized processing facilities, the number of intermediaries was reduced and farmers were able to bargain better.

Strategy promoted by BAIF to improve cashew production

1. Land survey and development of the land into small plots along the contour, to prevent soil erosion and to harness rain water;
2. Use of grafted cashew plants of elite varieties for establishing medium density plantation, with 7 x 7 m spacing;

Figure 3: Cashew value chain developed by BAIF



Source: ***Gupta, 2018***

3. Establishment of irrigation facilities, wherever possible to irrigate the orchard atleast in the initial years;
4. Introduction of good crop husbandry practices to facilitate better growth and yield;
5. Cultivation of inter-crops between cashew plants not only to generate additional income, but also to maintain the plantation in a healthy condition;
6. Appointment of field guides, who were local school dropouts trained in cashew cultivation, to visit all the orchards regularly and interact with each farmer to discuss about the activities undertaken and sort out the problems if any;
7. Bulk procurement of inputs, development of various infrastructure and services required for improving the production.
8. Promotion of micro-finance among group members and availing group loans from financial institutions.
9. Promotion of additional income generation activities and social development initiatives such as women empowerment, community health, education and literacy, developing pressure groups against social evils.
10. Series of People's Organisations such as Orchard owners' groups, consisting of 25- 30 families, village level planning committees, Block level Cashew producers' cooperatives with the leaders of the orchard owners' groups as representatives on the Executive Committee, etc were formed. The major role of these organisations was facilitation for members to adopt good orchard management practices and participate in developing backward and forward linkages. Several sub-committees were promoted to coordinate health care, education and women empowerment activities. These producers' cooperatives organized collection of agricultural produce grown by the members and further graded processed and marketed them locally.
11. A Farmers' producer company 'VAPCOL' was established later by

enrolling the cashew growers' cooperatives as members to process and market the produce.

Strategy for improving profitability in cashew industry

Cashew processing

Cashew being an international, high value cash crop, India has to compete with other leaders like Vietnam, Brazil and China in terms of quality and price. Hence, utmost care has to be taken to process RCN in an efficient way, with respect to size, colour, texture and taste. It has been demonstrated that mechanized processing, adopting the best technique of heating, can be labour efficient and least polluting, while yielding the highest percentage of unbroken kernels. Hence, the time has now come to consolidate the processing facilities with improved equipment and processing. Suitable credit facilities should be provided, at a competitive rate of interest to enable the local processing units to operate to their maximum capacity, competing with their international counterparts.

Suitable facilities should also be developed to process cashew nut shell liquid and cashew apple. There are many small-scale cashew processing units where the crude method of heating cashew nut, even by using cashew shell as fuel, is still in practice. While heating RCN and while burning cashew shell, very harmful smoke is released, polluting the surroundings. As this smoke is harmful, pollution-free processing must be adopted. As CNSL has good export demand, efficient processing will help to generate additional income, while preventing environmental pollution. Cashew apple is tasty and nutritious, which can be processed into juice, syrup, jam and alcohol. In the absence of processing facilities, cashew apple can also be fed to livestock. An economically viable processing plan should be developed to make best use of cashew apple.

Procurement of raw cashew nuts

Small cashew farmers are not aware of the prevailing price of cashew either in the local or international markets and there are no procurement centres offering a fair price. Hence, it will be ideal for the State Governments to organize cashew growers to form their groups/ associations and link with the reputed processers. Alternately, special weekly markets can be opened in cashew production clusters during the cashew harvesting season, where processers can directly participate in the purchase.

One good option will be to establish cashew producers' company where village level farmers' groups can be the members. The producer company can be the facilitator of the cashew value chain, to ensure backward and forward linkages. This company can be expected to professionally manage the business of procurement, processing and marketing of produce. These organisations will have the strength to negotiate with processors and retailers for better price. The Government of India has made provision for extending financial support to producer companies to cover the initial operating expenses. This opportunity can be encashed by small-scale cashew growers for better price realization.

To create better awareness among cashew growers about the cashew demand, supply and price fluctuations, the Directorate of Cashew and the Cashew Export Council may also take up the following initiatives:

1. Regular Market Survey on the demand and supply of RCN in international markets;
2. Provision of warehouse and credit facilities;
3. Suggested support price based on the prevailing price for imported RCN;
4. Offering suitable price to farmers by traders, based on the sample with a condition to deliver the agreed quantity within a stipulated period.

Boost cashew yield and production

Increasing RCN production through increase in the yield and plantation area should be an important goal of the Indian cashew Industry, which is most critical for regaining its leadership. For increasing cashew nut yield, there is scope in the following areas:

Re-establishment of old plantations: Plantations of 25-30 years age, should be monitored closely for the yield and trees less than 50 per cent of the average yield of 8-12 kg/ tree should be identified for replacement. If more than 50 per cent trees are poor yielders in the older plantations, it will be better to uproot all the trees and establish new plantation, with high density, at 4 x 4 m or 4 x 5 m spacing, using grafted plants of superior variety. While selecting the variety, it will be better to select a variety having large size nuts, as large size kernels fetch premium price. Even in the younger plantations, new saplings can be established between the older trees.

Good management practices: While establishing high density plantations, it is also necessary to adopt good orchard management practices, particularly to improve soil fertility and assured moisture supply during the critical stages of shoot development and fruit setting. Cashew is generally grown on sandy soils along the sea coast and on hilly slopes. These sites have to be treated differently.

The soils along the coastal areas are poor in nutrients and organic matter and high in sodium chloride with poor water holding capacity. As most of the coastal regions receive fairly good rains and the ground water table is fairly high, serious efforts should be made to improve soil fertility, reduce sodium chloride content and conserve moisture during the spring and summer seasons. Facilitation of in situ collection of rain water in the field and allowing it to percolate in the ground can help in draining the salt from the root feeding zone to a great extent. Rain water recharging will improve the ground water table. Surface drains can also be dug wherever necessary, to prevent waterlogging. In coastal areas, generally, the water table is high and no supplementary irrigation is necessary during spring season. However, in the areas where soil moisture is a serious constraint, 1-2 irrigations, preferably micro-irrigation may be provided.

Cashew plantations in the coastal areas are prone to inundation of sea water, resulting in suppressed growth and even in the death of cashew trees. High sodium chloride in soil prevents the intake of various macro and micro-nutrients by trees. Thus, efforts should be made to select cashew tree races, with have been thriving well on soils having high sodium chloride and other salts. Seedlings of these trees should be tested for their salt tolerance. Such genotypes can be used as rootstock to produce grafted plants for planted on salty lands. Genetic modification of cashew by incorporating salt tolerant genes should also be undertaken to establish cashew on sodic and saline wastelands. Special techniques of nutrient management should also be developed to ensure availability of required nutrients to cashew trees.

With regard to cashew plantations on hilly lands, soils in general are shallow and prone to heavy soil erosion. These plantations often suffer from moisture stress during the spring season, at the time of fruiting. To address this problem, these plantations should have strong contour bunds, which can promote soil and water conservation. This may be further followed by mulching of the ground to prevent soil moisture loss. It is very difficult to find water resources to irrigate these plantations and hence, moisture conservation is the answer. However, watering the plants during the first few years will help in preventing plant mortality.

Cashew leaves are leathery, high in fibre, tannin and other phytochemicals. Decomposition of dried cashew leaves fallen under the trees, generally take more than a year. These leaves remain under the

canopy, obstructing the percolation of the rain water in the ground. The leaves also release tannin and other chemicals in the soil, interfering with the absorption of nutrients by cashew tree. This problem should be addressed by developing a technique to shred the dried leaves on the site or to collect the litter, shred it and convert it into compost by treating with suitable microbes. The treatments can also address the decomposition of tannin and other phytochemicals. As the phytochemicals present in cashew leaf litter affect the intake of nutrients from the soil, special techniques such as placement of nutrient briquettes deep in the soil, application of soil amendments with nutrients, foliar application, etc. should also be introduced to boost the yield. In areas where rainfall is high, leguminous green manure crops can be grown during the rainy season, at least around the canopy to enrich organic carbon content in the soil.

Flower induction: It is well known that many plants can be artificially induced to flower by applying ethylene producing chemicals. In case of cashew, foliar spray of 10 to 50 ppm Ethrel, before flowering time has been effective in inducing flowering. The number of flowering panicles per square meter, number of perfect flowers per panicles and sex ratio across locations were better with Ehrel spray, atleast 3 weeks before the normal flower induction (Ghadage *et al.*, 2016). Generally, the flowering duration varied from 75 to 90 days but there was no impact of growth regulators on the duration. Foliar sprays of plant growth regulators had a positive and significant effect on the total number of perfect flowers and percentage of female flowers. This can be certainly tried where flowing intensity is low.

Improvement in the size and quality of kernels: As cashew kernels having larger size, in unbroken condition, will fetch the highest price, the aim should be to produce superior quality cashew nuts. Hence, preference should be given to varieties having large size cashew nuts. While developing new varieties, the aim should be to increase the kernel size along with the yield. It should also be possible to develop special nutrient management package, particularly the foliar application of micro-nutrients, such as calcium, boron, manganese and zinc, which play a very significant role in fruit set and nut development. Some of these micronutrients such as calcium can also help in improving the texture and hardiness of the kernel and reduce the brittleness. These nutrients are generally immobile in soils and hence, foliar applications are very effective. It is necessary to test the soils of cashew plantations and assess the availability of various macro and micro-nutrients and fix suitable doses of nutrients. Adequate studies have not been carried out in the past about the role of micronutrients and their availability under different soil conditions.

Plant protection: Plant protection is most critical for maintaining the productivity of the plantations. Important pests and diseases of cashew are listed below (Govt. of India, 2014):

Insect pests

1. **Mosquito bug:** *Helopeltis antonii* Signoret: Causes heavy economic losses, affecting 30 - 60 per cent drop in the yield. Both nymphs and adult bugs suck sap from tender flushes of shoots and inflorescences.
2. **Stem and root borer:** *Plocaederus ferrugenius* L.: It is a serious pest which causes death of tree
3. **Leaf miner:** *Acrocercops syngramma* Meyrick
4. **Leaf and blossom webber:** *Lamida moncusalis* Walker
5. **Flower thrips:** *Rhynchothrips raoensis* Ramakrishna Ayyar: Adult nymphs damage inflorescence.
6. **Foliage thrips:** *Selenothrips rubrocinctus* Giard; *Rhipiphorothrips cruentatus* Hood; *Retithrips syriacus*

Mayet: Adult nymphs damage lower surface of leaves.

7. **Mealy bug (*Ferrisia virata*):** Nymphs and adults suck tender parts of the plant
8. **Apple and Nut borer (*Thylocoptlia panrosema*):** Caterpillars attack the fruits and cause premature fruit fall.

Diseases

1. Dieback or Pink disease: *Corticium salmonicolor* Berk. & Broome
2. Damping off: *Phytophthora palmivora* (Butler)
3. Anthracnose: *Colletotrichum gloeosporioidesm* Penz. and Sacc.
4. Inflorescence blight: *Colletotrichum mangiferae* Kelker; *Phomopsis anacardii* Early & Punith
5. Shoot rot and leaf fall: *Phytophthora nicotianae* var. *nicotianae* Breda de Haan

Control of pests and diseases

The intensity of pests and diseases varies with the location and climatic conditions. Hence, based on the intensity, suitable control measures should be undertaken. General precautions to reduce the incidences of pests and diseases as recommended by ICAR, are presented below:

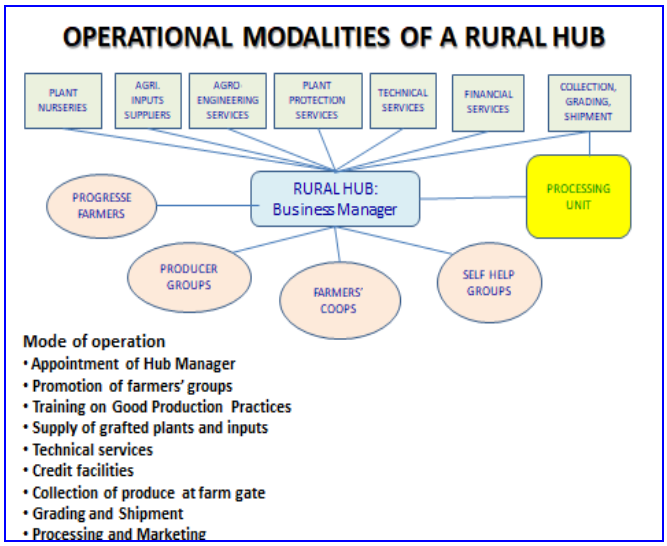
1. Selection of varieties' resistant/tolerant to major pests and diseases;
2. Selection of healthy planting material;
3. Treatment of planting material with pesticides especially bio-pesticides;
4. Maintain proper spacing;
5. Maintain good soil health, preferably by mulching and green manuring;
6. Good nutrient management, preferably by using manures and bio-fertilizers;
7. Controlled irrigation;
8. Regular monitoring of the field.

Depending on the recommendation, suitable pest and disease control measures must be carried out. Before using chemicals, it is necessary to ensure that no residue is left in cashew apple and nuts, to be able to meet the export regulations.

Support for small farmers

For small holders, apart from orienting them on good agricultural practices and providing them with infrastructural and financial support, there is also a need for hand holding, as they neither have self-confidence nor access to reliable resource agencies. They should be an important part of the Value Chain to enjoy a fair deal. To support small farmers, it is desirable to appoint village level field Business Coordinators / Managers, who can initiate action on behalf of small farmers, particularly for backward and forward integration. The manager based at the village or cluster level, depending on the volume of work, can coordinate procurement of inputs, arrange for various services, facilitate credit from financial institutions, provide technical guidance and also help in grading, processing and marketing of the produce, as presented in Figure 4. Such support can boost the confidence of farmers while increasing the crop yield and income. In the presence of the Business Manager, farmers need not negotiate with outside service agencies and marketing agencies directly.

Fig. 4: Rural business hub for backward and forward integration



The Business Hub can be operated by the Farmers' Organisations or Producer Company, and all the farmers will be the members of this organisation. The Business can organize various activities as listed in Fig. 4. There is scope for setting up startups to train unemployed youth to work as service providers with special skills and kits, under the Producer Company.

Summary and recommendations

Development of the Cashew Industry needs immediate attention of the policy makers, processors and farmers to remain competitive and profitable. There is scope to improve quality and profitability by adopting improved method of roasting and mechanized shelling of cashew nut. Agencies engaged in cashew processing, need financial support in the form of liberal loans with soft rate of interest. They also need support for establishing contact with reliable agencies to export to new locations. There is also scope for establishing cashew processing units in traditional cashew growing areas, particularly in African countries, which wish to process atleast 50 per cent of their harvest locally.

Increasing cashew production is another important opportunity, by increasing the crop yield as well as by expanding the area under cashew plantation. Presently, about 75 per cent plantations are owned by farmers while the rest are owned by the Government. More than 50 per cent plantations are old plantations, aged between 35 to 50 years, established with seedlings of nondescript genetic base, spaced widely and maintained without any recommended crop husbandry practices. These plantations should be closely monitored for their performance and trees yielding less than 4-5 kg nuts per year, should be replaced with new grafted plants of good varieties. The spacing between the trees can also be reduced to increase the tree population. Good crop husbandry practices such as improving soil productivity and moisture content and efficient management of nutrients, pests and diseases should be promoted by Agricultural Extension Agencies to increase the yield of nuts. There is good scope to promote cashew cultivation along the sea coast as a profitable cash crop. Suitable schemes should be developed to enable small farmers and absentee land owners to establish cashew plantations on unproductive lands. To provide timely support to small farmers and to improve their production, value chain can play a significant role. With efficient backward and forward linkages and increase in RCN yield, cashew can be more profitable than many other crops, including mango and other plantation crops. This will also help India to restore its leadership in cashew.

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