Crop Selection and Water Management of Non-Rice Crops by Farmers

by

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Dedicated to

My respectable parents

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Abstract

This study was carried out to understand the farmers' decision process regarding selection of non-rice crops and to find out their water management practices. The study was conducted during the Rabi season of 2008-09 at Shibchar Upazila of Madaripur district. Two descriptive models; one on the decision to grow a Rabi crop and the other on what Rabi crop would be grown. were developed on the basis of a questionnaire survey and discussions with the farmers. Water use by non rice crops in six selected fields was estimated on the basis of depleted average moisture in the crop root zone. A general (non-selected) farmers' survey was conducted to collect information on yield, input use, benefit- cost ratio (BCR) and farmers' awareness of crop management practices of BARI.

From the farmer's decision model, it was found that some farmers do not cultivate Aman rice because they want to start early in the Rabi season and grow onion/garlic or HYV wheat. Basically, they are the owner of high land and they believe that early Rabi crops are more profitable than the Aman rice. If the preceding Aman crop is harvested within November then the farmers with no access to capital and irrigation grow a mixed crop of mustard and lentil. On the other hand. farmers who have access to capital and irrigation, grow a mixed crop of onion and garlic.

From the water management analysis by farmers, it was found that the total crop water use of onion, garlic and wheat were 55.9 mm, 74 mm, and 107.8 mm, respectively. On the other hand, the potential crop water requirements were calculated for onion, garlic, and wheat as 165.8 mm, 276.2 mm. and 258.4 mm, respectively. It was evident from the research that the actual water use by onion, garlic and wheat as practiced by the farmers are almost one third, one fourth and two-fifths of the potential requirement. It was also evident from the research that the actual water use by onion, garlic and wheat as practiced by the farmers is almost 20%, 28% and 37% of the water requirement recommended by BARI.

From the yield and profitability analysis, it was found that the yields of onion, garlic and wheat under farmers' practice were 6.65 t/ha, 0.92 t/ha and 1.9 t/ha, respectively. The BCR of growing onion, garlic and wheat were 2.46, 0.65 and 1.33, respectively. From the research it was observed that the farmers do not follow the BARI recommended irrigation and fertilizer as inputs. As a result, their yields were lowered by almost 26%, 81% and 53% of the yields of onion, garlic and wheat obtained by BARI, respectively. It was also evident from the general survey that the farmers are aware of the impacts of irrigation and input use on yield. But they do not know when and how much of irrigation and other inputs to apply. The price of non-rice crops in the preceding year strongly influenced the use of inputs and a pre-set price of non-rice crops would encourage the use of inputs and increase the yields.

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List of Abbreviations

BBS	Bangladesh Bureau of Statistics
BADC	Bangladesh Agricultural Development Corporation
BCR	Benefit- Cost Ratio
BARI	Bangladesh Agriculture Research Institute
BMD	Bangladesh Meteorological Department
CPE	Cumulative Pan Evaporation
CRI	Crown Root Initiation
cm	Centimeter
DFCM	Depletion of Field Capacity Moisture
DAT	Days After Transplanting
DAS	Days After Sowing
DAE	Department of Agricultural Extension
ET_c	Crop Evapotranspiration
PE	Pan Evaporation
ET_o	Reference Evapotranspiration
FAP 4	Flood Action Plan 4
FAO	Food and Agriculture Organization
HYV	High Yielding Variety
ha	Hectare
ID	Irrigation Depth
IW	Irrigation Water
K_c	Crop Coefficient
LLP	Low Lift Pump
MPO	Master Plan Organization
MP	Murate of Potash
mm	Millimeter
t/ha	Ton per Hectare
pH	Negative logarithm of hydrogen ion concentration
SRDI	Soil Resource Development Institute

TSP	Triple Super Phosphate
USDA	U.S Department of Agriculture

Chapter One

Introduction

1.1 Introduction and Background of the Study

The cropping pattern in Bangladesh is predominantly rice based and non rice crops grow in only about 21% of the total cropped area (BADC, 2007). In terms of area coverage, the major non-rice crops are wheat (4.45%), rape and mustard (3.08%), lentil (1.54%), potato (1.13%), chili (1.05%), and onion (0.58%). Although abounding literature on water management practices and their effects on yields of rice are available, little is known about such aspects of non-rice crops. Most non-rice crops are grown during the Rabi (winter) season (December-March). As such, the amount of rainfall is not only insufficient but its distribution also fails to synchronize with water requirement of non-rice crops. Consequently, the yields of most non-rice crops are very low compared to the international standards. For example, the average yield of onion is only 6.5 t/ha which in very low as compared to the world average yield of 18.1 t/ha. The average national yield of garlic and wheat are 2.9 t/ha and 1.9 t/ha. which are very low as compared to those of other garlic and wheat producing countries (SAC, 2007). The yield of onion in some developed countries like Korea, the Netherlands, Japan and the USA have been reported to be 61.9, 54.1, 44.4 and 44.1 t/ha, respectively (Pathak, 1994). Even in India, the average yield of onion is 10.4 t/ha (Kumar et al., 2007).

Every year the country is facing an acute shortage of non-rice crops like pulses, oilseeds, spices etc. due to lack of proper management in the fields of irrigation, disease control, quality seed production etc. Besides, the cultivated area of non-rice crops in Bangladesh has also not significantly increased during the past decades (BBS, 2002). For example, the current demand of onion in the country is 730,000 metric tons while the production is only 150,000 metric tons (BBS, 2003). The national production of garlic is 35,000 metric tons against the demand of about 150,000 metric tons (BBS, 2004). These huge deficits of onion and garlic are being met up by importing them in exchange of our hard earned foreign currency. A large portion of this deficit can be extenuated by proper management practices, especially emphasizing on irrigation and other input managements.

The constraints of agricultural development in the South-Central region of Bangladesh are floods during the Aman season and non-availability of irrigation facilities during the Rabi season. The studies by MPO (Harza et al., 1986) show that out of the total area of the region, about 70% is normally flooded by the Padma-Meghna river system and the rest of the area is vulnerable to storm surges. MPO studies (Harza et al., 1987) have also shown that because of ground water salinity about 53% of the region is not suitable for irrigation development by groundwater. At present only about 20% of the agricultural area is irrigated of which about 26% is irrigated by ground water and rest is by surface water (BADC, 2005).That is why, the cultivation of HYV rice (Boro) is low in Rabi season in South-Central region.

Thus, due to irrigation development constraints, the cultivation of non-rice crops like onion and garlic that require little or no irrigation is increasing day by day in the South-central region. For example, in Faridpur region, the cultivable area of onion was about 6500 ha in 1999-2000 and this area has increased to 12300 ha in 2003-2004. Even the cultivable area of garlic has increased over the five year period. Also, the cultivable area of garlic was almost 2500 ha and this area has increased to 3400 ha during the same period of 1999-2000 to 2003-2004 (BBS, 2004).

The overall soil texture of South-Central region is silty loam and loam and as such, these types of soil are suitable for growing non-rice crops. It has been reported that the cultivation of non rice crops like wheat, onion, garlic, vegetable and potato by applying little or no irrigation are more profitable than growing the Boro crops in this region in Rabi season. (SRDI, 2001).

Although farmers get more profit through the cultivation of Rabi crops but their yields are very low compared to international standards. Bangladesh Agricultural Research Institute (BARI) has recommended the number of irrigation regimes and fertilizer doses for non-rice crops such as wheat, potato, lentil, onion, garlic, and tomato etc. (BARI, 1997). It is not known to what extent the farmers have adopted these regimes and doses and also their impacts on the crop yields. Application of irrigation water and fertilizer without proper planning based on crop demand results not only in wastage of inputs but also hampers crop growth and yield (Islam, et al. 1991). This study has attempted to find out the farmers' decision regarding selection of non-rice crops in Rabi season, their water management practices and the profitability of growing non-rice crops.

1.2 Objectives of the Study

The specific objectives of the study are-

- To understand the farmers' decision process regarding selection of non rice crops.
- To understand the water management practices from farmers' perspective for non rice crops.
- To determine the effects of water management on yield attributes and profitability of non-rice crops.

Chapter Two

Literature Review

Many studies have been conducted in many countries on irrigation management practice and profitability of non rice crop like wheat, onion, garlic, vegetables etc. In Bangladesh some works have been done in these aspects. An attempt is made here to review the most relevant studies.

2.1 Water Management of Non-rice Crops

The yield of non-rice crops like wheat, onion, garlic, potato, tomato etc. are influenced by many factors such as water management, nutrient management, disease control and soil condition etc. It was observed that the country's production and area of onion, garlic and wheat have increased over the last 20 years. During the period of 1985-86, the yield of onion, garlic and wheat were 3.8 t/ha, 2.9 t/ha and 1.4 t/ha, respectively. In the same period, the area of onion, garlic and wheat were 33.6, 12.5, 540.2 thousand hectare, respectively. The yield and area of these crops were sharply changed during the period of 2005-06 except wheat. The yield of onion, garlic, and wheat were 6.5 t/ha, 3.8 t/ha, and 1.5 t/ha in 2005-06 and the area of these crops were 115.6, 26.6, and 479 thousand hectare, respectively (BBS, 2006). In the following sections the water and fertilizer management practices and yields of onion, garlic and wheat have been reviewed.

2.2 Water Management and Yield of Onion

Proper irrigation management, based on timely measurements or estimates of soil moisture content and crop water needs, is one of the most important management practices for obtaining optimum yield. Effective water management requires knowledge of soil water-holding capacity, current available soil moisture content, crop water use or evapotranspiration (ET), crop sensitivity to moisture stress at current growth stage, irrigation and effective rainfall received, availability of water supply and length of time it takes to irrigate a particular field.

A field experiment was conducted at the regional agricultural research station in BARI Joydebpur, Gazipur. The soil of the experimental field was silty loam in texture. The effects of irrigation on onion yield are presented in Table 2.1. The highest yield of 9 t/ha was obtained with 6 irrigation at 10 days interval. The table also depicts that the amount of irrigation water applied increased with increase in yield. The benefit- cost ratio was also highest for 10 days interval (1.92). The benefit cost ratio of 0.74 less than one in the control treatment indicates the dire necessity of irrigation in onion production.

Table 2.1 Effect of irrigation on yield and profitability of Onion Practiced by BARI.

Item	Different irrigation sequences				
	No Irrigation	10 days interval irrigation	15 days interval irrigation	20 days interval irrigation	30 days interval irrigation
Total water use (mm)	120.5	279.5	239	220	187.5
Yield (ton /ha.)	3.26	9.01	8.71	7.70	6.44
Benefit-cost ratio	0.74	1.92	1.89	1.71	1.46

Source: Biswas et al., 2003

Saha et al. (1997) compared yield and water use of onion (cv. Taherpuri) under different irrigation schedules in Bangladesh. The irrigation treatments were no irrigation, irrigation at 40, 30, 20 or 10% depletion of field capacity moisture (DFCM); irrigation with 30 mm water at irrigation water / cumulative pan evaporation (IW/CPE) ratios of 0.50, 0.75 or 1.00. They found that the plots irrigated at 10% and 20% DFCM produced bulb yields of 16.3 and 16.3 t/ha, respectively, which were about 140% higher than that in the unirrigated control plot (6.8 t/ha). They also found that the yields of plots irrigated either at 30 or 40% DFCM (14 and 11.3 t/ha, respectively) were significantly higher than that of the control plot but still remained at a suboptimum level. They concluded that for optimum exploitation of the yield potential of Taherpuri onion with maximum efficiency of irrigation water use, 10 to 20% DFCM might be the most suitable criteria for irrigation in areas with similar condition.

Islam et *al.* (1999) conducted a field experiment to observe the effect of different irrigation treatments on the production of onion (cv. Taherpuri) at Joydebpur, Gazipur, Bangladesh. They compared seven irrigation levels viz. no irrigation, a single irrigation at 20 days after transplanting (DAT), a single irrigation at 40 DAT, irrigation at 10 days interval up to 40, 60 and 80 DAT, respectively aud irrigation at 10 days interval up to 80 DAT. They recorded the highest yield (9 t/ha) from the treatment irrigated at 20 days interval up to 60 DAT and the total water required by this treatment was 125 mm.

Numerous studies have been carried out in the past in a number of countries on irrigation management and yield of onion.

Siugh el at. (1987) studied the effect of irrigation and nitrogen levels on yield attributes of onion (*Allium cepa* L.) cv. Pusa Red in north India. They applied 1, 2, 3 or 4 irrigations with 50 mm of water at 20-days intervals and fertilized with N at 0, 60, 90 and 120 kg/ha. They recorded the highest bulb yield of 19.6 ton/ha with the highest N and irrigation rates.

The effects of irrigation on the yield, size grade distribution, bulb quality, chemical composition and storage of onion bulbs were studied by Chung (1989) in India. He observed that applying irrigation throughout the season increased the total bulb yield from 48 to 52 t/ha.

The four irrigation levels of 25, 50, 100 and 150% of daily evapotranspiration were compared by Galbiatti et al. (1992) to study the effect of irrigation on development and productivity of onion. They recorded the highest number of leaves/plant, plant height, bulb diameter and bulb weight with the two highest water levels (100 and 150%).

An experiment was conducted by Patel *et al.* (1992) in India to study the effect of 3 irrigation rates (1W/ CPE ratio of 1, 1.2 and 1.4), 3 rates of Nitrogen (40, 80 and 120 kg/ha) and 3 rates of P_2O_5 (20, 40 and 60 kg/ha) on onion. They recorded the highest yields with an IW/ CPE ratio of 1.2 or 1.4 (33 t/ha and 32.5 t/ha, respectively) and with P_2O_5 of 60 kg/ha (33 t/ha). Nitrogen did not affect the yield. They also observed that N and P uptake were greater with IW/ CPE ratio of 1.2 or 1.4 than with ratio of 1.0.

Sharma et al. (1994) investigated the effects of irrigation (IW/ CPE ratio of 0.6, 0.8, 1.0 or 1.2) and nitrogen (0, 50, 100 or 150 kg/ha) on onion yields during 1984-86 in Rajasthan, India. They observed the highest yield at the highest irrigation and nitrogen treatments. High consumptive uses and water use efficiencies were also observed with increasing levels of irrigation and increasing rates of nitrogen.

Abu-Awwad (1996) also studied onion yield, rainfall distribution, water use efficiency (WUE) and water use index (WUI) as affected by four increasing water quantities (0.25, 0.50, 1.0 and 1.5 time the evaporation from Class A pan) in the field plot experiment during 1991/92 and 1992/93 in the Jordan valley, Jordan. He observed that with supplemental irrigation, winter onion production per unit area can be increased by two or three times the non-irrigated onion. Maximum WUE was recorded in 0.25 times evaporation, while the maximum WUI was also recorded in the same treatment.

Neeraja et al. (1999) conducted a field experiment to investigate the effect of irrigation and nitrogen on growth and yield of rabi onion *(Allium cepa L)* in Andhra Pradesh, India. They used four levels of irrigations given at IW/ CPE ratios of 0.6, 0.8, 1.0 and 1.2 and five levels of nitrogen at 0, 50, 100, 150 and 200 kg/ha. Among the various treatments, higher level of irrigation (1.2 IW/ CPE) and nitrogen (200 kg/ha) alone and their interaction resulted in maximum plant height, more number of leaves per plant, maximum bulb length, bulb diameter, bulb weight and bulb yield. Depending upon the fertility of the soil, they recommended irrigation at 1.2 IW/ CPE and nitrogen from 150-200 kg/ha for obtaining the highest bulb yield of onion.

The response of onion *(Allium cepa L)* to different irrigation schedules was studied by Orta and Ener (2001) in Trakya, Turkey, during 1997 and 1998. The crop was subjected to four irrigation treatments according to available soil water depletion fractions (0.30, 0.50, 0.70 and no irrigation). Irrigation thresholds (amount of soil water at 0.40 m depth) were used as the criteria to initiate drip irrigation. They recorded the highest yield from the plots to which irrigation water was applied at a soil water fraction level of 0.30. To maintain the soil moisture depletion level at 0.30, it required

339.4mm (in 14 applications) and 227.2 mm (in 13 applications) water for irrigation in 1997 and 1998, respectively.

Kumar et al. (2007) conducted a study at the research farm of Central Institute of Post Harvest Engineering & Technology, Abohar, Punjab, India during the period from January to May of 2004 and 2005 to analyze the response of onion to different irrigation levels with microsprinkler irrigation system. They applied four different irrigation levels. These were, irrigation water (IW) to cumulative pan evaporation (CPE) ratios of 0.60 (T1), 0.80 (T2), 1.0 (T3) and 1.20 (T4). They found best yields of 32.8 t/ha and 34.4 t/ha from T3 and T4 treatments in 2005, respectively. The applied irrigation water for T3 and T4 were 389.2 mm and 451.3 mm, respectively.

From the above citations, it was found that, irrigation significantly increased the yield of onion. As the frequency of irrigation increased, the yield also increased.

2.3 Water Management and Yield of Garlic

Both nationally and internationally, not much literature is available found on the water management and yield of garlic.

A study was carried out on garlic (cv. BARI Rashun-1) during the Rabi season at the experimental field of irrigation and water management division, BARI, Gazipur. Soil moisture content was monitored at the depth of 0, 15, 30 cm from the surface. The results obtained from the field experiment are presented in Table 2.2. It should be noted that irrigation at 15 days interval produced the highest yield (4.9 t/ha) but did not show significant difference with 25, 50, 75 days after plant. As the treatment, irrigation at 15 days interval was watered most frequently, the highest amount of water was used by the same treatment and the yield was the highest.

The Table 2.2 also shows that garlic cultivation applying irrigation at 15 days interval was found most profitable that is highest benefit-cost ratio of 2.20 among all the irrigation sequence.

Table 2.2 Effect of irrigation and profitability from different irrigation of garlic practiced by BARI, 2007-2008.

Item	Different irrigation sequences						
	Rainfed	Irrigation at 25 DAP	Irrigation at 50 DAP	Irrigation 25 and 50, DAP	Irrigation at 25, 50, & 75 DAP	Irrigation at 15 days interval,	Irrigation at 20 days interval
Total water use, mm	139	162	198	212	232	261	229
Yield, (ton/ha.)	2.839	3.086	3.269	3.365	4.21	4.92	4.68
Benefit-cost ratio	1.34	1.44	1.53	1.55	1.92	2.20	2.13

Source: Sarkar et al., 2008 DAP: days after planting

Sadaria et al. (1997) carried out a study at Junagadh, Gujarat, India during the winter of 1991-92 and 1992-93 to understand the effects of irrigation on garlic. They use different conditions like: irrigation water/cumulative pan evaporation ratios (IW/ CPE) of 1, 1.2 and 1.4, Nitrogen application of 25, 50 and 75 kg/ha and Phosphors application of 11, 22 and 33 kg/ha for garlic. In that study the highest bulb yields (5594 kg/ha) were obtained at 1.4 IW/ CPE during 1991-92.

Hanson et al. (2003) conducted a study at west side of the San Joaquin Valley in California of USA to investigate the effect of irrigation frequency, irrigation water cutoff date and the amount of applied water on garlic yield. They applied different irrigation frequencies those were irrigation per week, irrigation per 1.5 weeks and irrigation per 2 weeks. They reported that the highest yield was obtained from irrigation per week.

Cortes et al. (2000) conducted a study at Regional Water Research Centre of Castilla-La Mancha University Campus in Spain to see the effect of deficit irrigation at three crop stages (vegetative development, bulbification and ripening) of garlic. They found that the treatment with no deficit irrigation during the ripening stage give the highest productions. It was also found that the deficit imposed at the ripening stage affects mainly the quantity (yield) and the deficit imposed at the bulbification and ripening stages affects both quantity and quality (size).

Ayars (2007) conducted a study at west side of the San Joaquin Valley in California of USA to determine the crop coefficient and water requirement of irrigated garlic. He used different irrigation systems such as flood irrigation, subsurface drip irrigation, and surface drip irrigation and irrigation levels were set at 50, 75, 100, and 125% of crop evapotranspiration measured using a weighing lysimeter. He found that the total yield has a relation to the total applied water with a maximum occurring at one hundred percent ETc.

From the above references, it was found that, irrigation significantly increased the yield of garlic. As the frequency of irrigation increased, the yield also increased.

2.4 Water Management and Yield of Wheat

A field experiment was carried out during Rabi season of the years 2007-2008 on wheat (cv.Kanchon). The field study was conducted in Jamalpur. The texture of the soil was clay loam. The results obtained from the field experiment are presented in Table 2.3. It should be mentioned that, irrigation at 21, 45, &65 days after sowing (T_2) obtained highest yield (4.1 t/ha). The Table 2.3 also showed that wheat cultivation applying irrigation at 21, 45& 65 days after sowing (T_2) was found more profitable with the highest benefit-cost ratio of 3.30 between the two irrigation sequences.

Table 2.3 Effect of irrigation and profitability of Wheat Practiced by BARI.

Item	Irrigation sequences	
	No irrigation (Rainfed)	Irrigation at 21, 45, & 65 days after sowing)
Total water use, mm	159	291
Yield, (t/ha.)	2.91	4.1
Benefit-cost ratio	2.58	3.35

Source: Sarkar et al., 2008

Khan et al. (1985) conducted a study to asses the effect of irrigation and tillage practice for wheat cultivation at Ishurdi, Jessore and Dinajpur District in Bangladesh. They found that the highest grain yield of 2.63 t/ha with two irrigations (at 20, 50 day after seedling) and 4.8 t/ha with three irrigation (at 17, 50, 70 day after seedling).

Rahman and Islam (1985) conducted an experiment in Bangladesh to see the effects of irrigation and tillage on the yield and water relations of wheat. They used 4 irrigation treatments: no irrigation (W0), irrigation of 5 cm at 4 weeks after planting (W1), W1 + irrigation(s) of 5 cm each when the ratio of irrigation water (5 cm) to cumulative pan evaporation (IW/CPE) reaches 0.75 (W2); and W1 + irrigation(s) of 5 cm each when the IW/CPE ratio reaches 0.50 (W3). They found that deep tillage coupled with 1 irrigation at 4 weeks after planting produced the highest yield (2.96 t/ha).

Ghazy et al. (1986) conducted an experiment with three levels of irrigation viz: 30% 50% and 70% depletion of available soil moisture (ASM) at the Bangladesh Institute of Nuclear Agriculture (BINA) farms, Mymensingh during December 1983 to April 1984. They found the highest grain yield of 4.2 t/ha and water use efficiency of 1.87 kg/m^3 with irrigation after 70% depletion of ASM and the highest straw yield of 8.52 t/ha with irrigation after 50% depletion of ASM.

Ali and Sitara (2004) conducted a study at the Botany Field Laboratory, Bangladesh Agricultural University in Mymensingh during Rabi season from November 2001 to March 2002 to investigate the effect of irrigation frequencies on the yield and yield attributes of the wheat cultivar 'Shatabdi'. They used Irrigation treatments as. T_0=no irrigation (control), T_1= one irrigation at 21 DAS. T_2= two irrigations at 21 and 45 DAS, T_3= three irrigation at 21, 45 and 60 DAS and T_4= four irrigation at 21, 45, 60 and 75 DAS. They found that grain yield (3.52 t/ha), straw yield (4.22 t/ha) and harvest index (45.25%) were significantly higher in T2 treatment than those of other treatments. They also found that two irrigations at 21 and 45 DAS significantly enhanced the growth, yield attributes and yield of wheat over other treatments.

Ali et al. (2007) carried out a field experiment at the Department of Irrigation & Water Management farm, Bangladesh Agricultural University in Mymensingh to see the effects of water deficit on yield, water productivity and net return of wheat. They found that the highest grain yield was obtained with the no-deficit treatment. They also found that yield attributes were affected by deficit irrigation treatments.

Numerous studies have been carried out in the past in a number of countries on irrigation management and yield of wheat.

Ram and Singh (1976) conducted a study at Rajasthan in India during the period of 1971-1972 to optimize the scheduling of irrigation for wheat in light soils. They obtained higher grain yields (3.9 t/ha) of wheat with one irrigation at crown root initiation (CRI) stage (22 days after sowing) and further irrigation applied at 40% available soil moisture then at 30% available soil moisture.

Peck and Kirkham (1979) carried out an experiment at the Panhandle Research Station, Goodwell, Oklahoma during the period of 1977-1978 growing season. They planted seed of certified hard red winter wheat (*Triticum aestivum* L. em. Thell.) on 13 Oct. 1977 for the three treatments (normal irrigation schedule, modified irrigation schedule, and dry land). They found that yields were highest for the modified treatment (average yield: 4470 kg/ha) and were 23% more than yields for the plants under the normal irrigation schedule (average yield: 3640 kg/ha). They also found that average yield of dry land plants was 1660 kg/ha.

Mugabe and Nyakatawa (2000) conducted a stndy at Chiredzi Research Station in Zimbabwe during the winter seasons of 1996 and 1997 to assess the possibility of growing wheat on residual soil moisture. They studied on six wheat genotypes (P1, P2, Pote, Deka, Nata and Ruya) under three irrigation regimes. They applied different irrigation regimes like supplying irrigation water according to the crop water requirements, supplying three quarters of the crop water requirements and half of the crop water requirements at each irrigation day. They also found that three quarters and half of the crop water requirements result in a yield decrease of 12% and 20% in 1996 and 7% and 20% in 1997 season, respectively. They also found that P2 gave the highest yields on an average for the two seasons and was the least affected by deficit irrigation.

Mahmood and Ahmad (2005) conducted an experiment at the research area of the Water Management Research Centre, University of Agriculture in Faisalabad during the period of 2003-04 Rabi season to know the water reqnirements and response of wheat at different soil moisture depletion levels. They found that maximum (2966.5 kg/ ha) grain yield of wheat was obtained when it was irrigated at 50% soil moisture depletion (SMD). They also found the grain yield of 2319.1 kg/ ha with irrigation at 70% SMD.

Zhang et al. (2006) conducted a field experiment at an arid area in China during the period of 2003 - 2004 growing seasons to evaluate the effects of regulated deficit irrigation on yield performance of spring wheat (*Triticum aestivum*). They found that regulated deficit irrigation treatment subjected to medium soil water deficit both during the middle vegetative stage (jointing) and the late reproductive stage (filling and maturity or filling) while subjected to no soil water deficit both during the late vegetative stage (booting) and the early reproductive stage (heading) give the highest yield (3.7 t/ha) increase of 25% and 14% of significant water saving.

Shao et al. (2008) carried out a study in the North China to investigate the grain yield, water use efficiency (WUE) and root water uptake of winter wheat (*Triticum aestivum L.*) for five seasons under different irrigation frequencies associated with limited water supply. They reported that the highest wheat yield (3.17 t/ha) was obtained from three irrigations. They also found that good soil moisture conditions at sowing also play an important role in achieving high yields of this crop under limited water supply.

Chapter Three

Research Methodology

3.1 Introduction

The study was conducted in four villages, namely, Babu Mullah Kandi, Hazi Kandi, Munsi Kandi and Mullick Kandi of Shibchar Upazila of Madaripur District Shibchar is a deeply flooded area and the second populous Upazila of the District. The cropping pattern in the Upazila is rice based but unlike most other Upazilas, non rice crops grow in about 43% of the total cropped area. In terms of area coverage, the major non-rice crops are jute (10.4%), onion (11.5%), garlic (9%), wheat (7%), and lentil (1 13%) etc. But little is known about the farmers' decision process regarding selection of non-rice crops, water management practices and their effects on yields

3.2 The Study Area

3.2.1 Location and Area

The study area is located in the South-Central region of Bangladesh. The study area lies between latitude $23^0 15'$and $23^0 30'$ North and longitude $90^0 05'$and $90^0 18'$ East. The Upazila is bounded on the North by Srinagar Upazila, on the East by Louhajong and Zajira Upazilas, on the South by the Madaripur Sadar and on the West by the Sadarpur and Bhanga Upazilas The total area of the study site is 32189 hectare and the population is approximately three million. The location map of the study area is shown in Figure 3.1.

3.2.2 Geology and Soil

The study area consists of recent holocene alluvial deposits and predominantly consisting of fine sand, silts and clay. The low land and medium low land soil is clay to loamy, high land and medium high land soil dominates with sandy loam to silty loam textures all over the area. The amount of organic substance is 0 66% and pH, 8.3. In this soil, the amount of calcium, magnesium and phosphorus are 42.2%, 2.7% 11%, respectively, whereas the amount of nitrogen is 0 10% (SRDI, 2001).

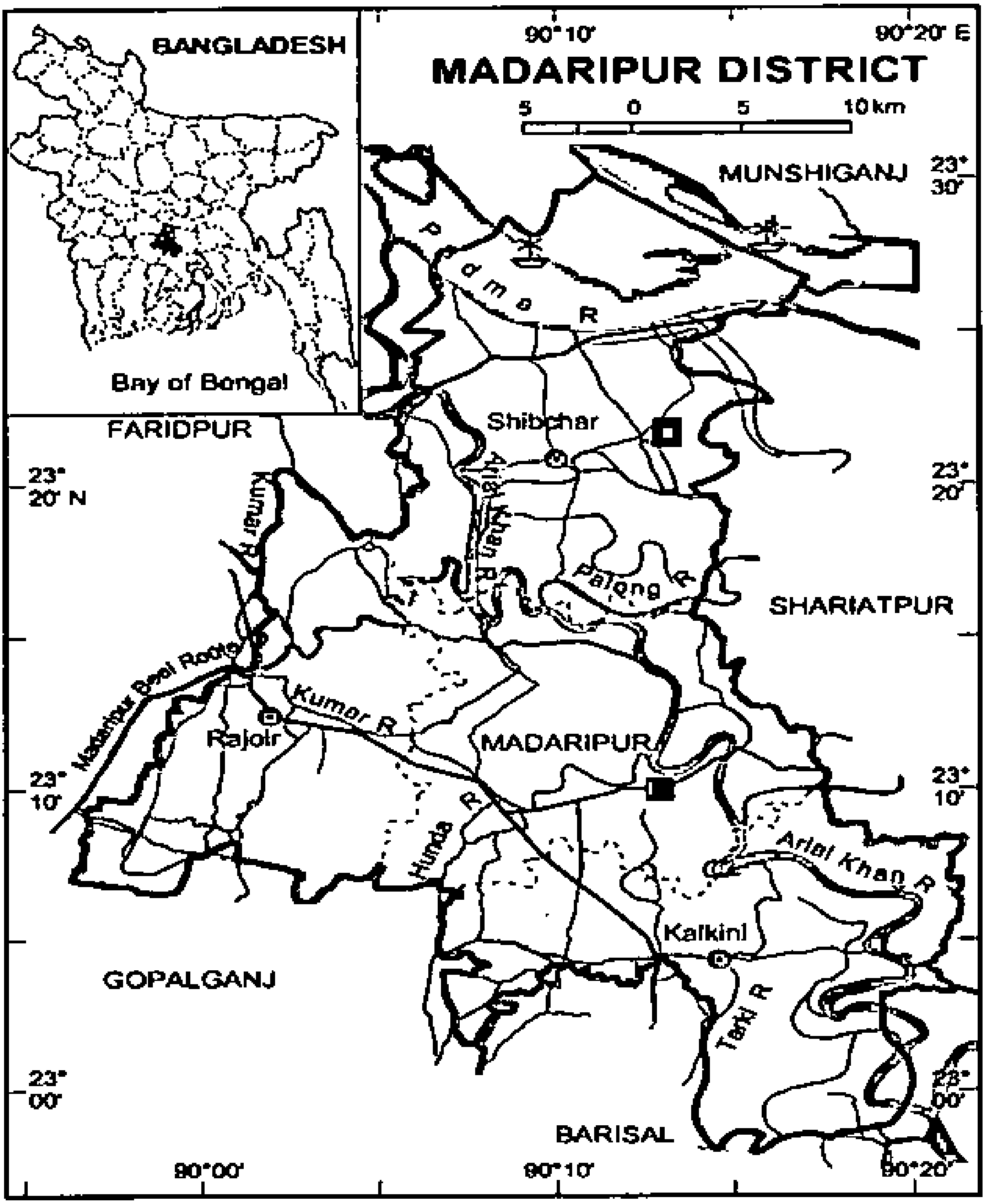


Figure 3.1 Map of the study area

Legend
Study area

3.2.3 Climate

Shibchar has a subtropical and tropical climate. The climatic conditions of the study area vary within a relatively narrow range. Variations of temperatures, humidity, and annual rainfall, wind (speed and direction) during 1985-2007 period were collected from the Bangladesh Meteorological Department (BMD). The annual mean temperatures in Madaripur varied from 25.7^{0}C to 26.8^{0}C within the 1983 to 2007 period. The highest maximum and lowest minimum temperatures were recorded as 39.6 ^{O}C (March, 1999) and 10 ^{O}C (December, 1981) respectively. The annual total maximum and minimum rainfalls were recorded as 3028 mm (1986) and 1169 mm (1994) for the study area. Monthly prevailing wind speed varied from 1.5 knots in east direction to 6.4 knots in south direction, respectively (BMD, 2007).

3.2.4 Land Use Pattern

The total agricultural area is 27360 hectare occupying about 85% of the total area of the Upazila. In this area, 75% of cultivable land is medium highland or F1 (flooded depth of 90 cm from two weeks to three month) and 10% is medium lowland or F2 (90-180 cm flooded continuously for several months). Houses and homestead occupy 5% of the area. About 3% of the land is fallow, 3% of the land is plantation and rivers and water bodies occupy 2.5 % of the land.

3.2.5 Agricultural Crops and Cropping Pattern

The major cropping patterns of the study area are B.Aus and B.Aman- Rabi crops, B.Aus /Jute-rabi crops, Deep water Aman-HYV Boro etc. The major cropping patterns are shown in Table 3.1. The cropping intensity of Shibchar Upazila is 209%.

3.2.6 Area and Yield of Major Non-rice Crops

The area and yield of major non-rice crops of Shibchar as collected from the Upazila agricultural office are presented in Table 3.2. The average yields of onion, garlic, and wheat were higher in the last year because these crops were under irrigation (average one).

Table 3.1 Cropping Pattern in the Study Areas

Serial no.	Land type	% of land	Major crops
1	Medium High land	10%	Rabi: Wheat, Onion, Garlic, Mustard, Lentil, Coriander Seed, Potato, etc.
			Kharif-1:B.Aus or Jute
			Kharif-2: T. Aman
		30%	Rabi: Wheat, Onion, Garlic, Mustard, Lentil, Coriander Seed, Potato, etc.
			Kharif-1: B.Aus or Jute
		35%	Rabi: Wheat, Onion, Garlic, Mustard, Lentil, Coriander Seed, Potato, etc.
			Kharif-1: Mixed B.Aus and Aman
2	Medium Low land	10%	Rabi: HYV Boro
			Kharif-2: Deep water transplanted Aman.

Sources: Upazila Agriculture Office, 2008

Table 3.2 Statistical Data of Major Non-Rice Crops in Upazila Shibchar.

Item	2007-2008		
	Cultivated land (ha.)	Yield (t /ha.)	Average yield of last five years (t/ha)
Wheat	1765	2.18	1.9
Onion	3240	8.50	8.42
Garlic	2310	4.0	3.6
Total	7315		

Source: Upazila Agriculture Office, 2008

3.3 Data Collection

The study is based on both primary data and secondary data. Primary data were collected to understand the farmer's decision regarding crop selection and water management of non-rice crops. Secondary data were collected for the computation of the crop water requirements and the understanding of the present status of the non-rice crops. Secondary information such as statistical data, reports, maps have been collected from various Government and Non-Government organizations (BMD, BARI, BCL etc).

3.4 Farmer's Decision Model on Crop Selection

A two stage descriptive model on decision to grow a Rabi crop and selection of the Rabi crop was developed based on the information collected from the questionnaire survey and discussion with the farmers. The decision criteria were then modified using a decision tree, which was then again tested on the farmers to predict the decisions made by them and also to ascertain the validity of the developed models. Such descriptive models have been developed in the past to understand how farmers make decisions in the real world and the steps they go through in the process (Intal and Valera. 1990; Lampayan et.al., 1994 and Saleh et al., 2002).

The study was carried out in four villages at Shibchar Upazila (Kathal Bari Union) during the Rabi season of 2008-2009. These villages were located approximately 200 m from each other and are connected by a village road. The location of the study area is shown in Figure 3.1. For the development of the decision model, forty sample farmers were randomly selected. The selected farmers represent almost one fifth of the total farmers of the selected four villages. The decision model was developed by surveying 30 farmers (75% of the sample) in four villages. After development of the decision model, it was tested at field level by surveying the rest 10 farmers (25% of the sample).

3.5 Assessment of Water Use of Selected Crops

When the farmers have decided to grow Rabi crops, attempt was made to estimate its crop water use from residual soil moisture and rainfall. From the analysis of secondary data and also from the information collected during the field visits, three major non-rice crops in the study area were found onion, garlic and wheat. In order to quantify the crop water use, the field water status was closely monitored in six farms with these three Rabi crops (two from each onion, garlic and wheat). The soil moisture contents were measured at 0, 15 and 30 cm depths (onion and garlic) and 0, 25, and 50 cm depth (wheat) using the gravimetric method. The measurements were made at 15-day interval to quantify the soil moisture depletion during the crop growth period. These depths were selected because the effective root zone depth of onion and garlic is 30 cm (Kumar et al., 2007) and that of wheat is 50 cm (Laghari et al., 2008).

Water use by selected crops were estimated on the basis of the depleted average moisture contents in the crop root zone which is the product of the average depleted soil moisture, bulk density of soil and root zone depth of crops. Water use by crops was obtained from the following equation:

$$\text{Water use} = \Delta\theta \text{ X } A_s \text{ X } d \qquad (3.1).$$

Where, $\Delta\theta$ = % of depleted moisture, A_s = Apparent specific gravity of crops, and d = root zone depth of crops.

3.6 Determination of Potential Crop Evapotranspiration (ET_c)

Although there are many methods for estimating evapotranspiration but for the present study, Penman-Montieth method using CROPWAT software developed by FAO (Smith, 1992) was used. For this purpose, the weather parameters required for using CROPWAT were collected from FAP 4, South West Region (Halcrow et al., 1993). Potential crop evapotranspiration (ET_c) was obtained from he following relationship (Doorenbos and Pruitt, 1977)

$$ET_c = ET_0 \times K_c \qquad (3.2)$$

Where, ET_0 is the evapotranspiration measured by CROPWAT in mm/day and Kc is the crop coefficient. The Kc values were obtained from MPO (Harza, 1984). The 10-day period K_c values are mentioned in Table 3.3.

Table 3.3 10-day period Crop coefficient of Bangladesh.

Item	1	2	3	4	5	6	7	8	9	10	11
Wheat	0.45	0.57	0.74	0.54	1.07	1.17	1.15	1.12	1.03	0.88	0.50
Onion/Garlic	0.43	0.53	0.68	0.84	0.96	0.99	1	1	1	0.99	0.97

Source: MPO, 1984

3.3.6 Textural Classification and Bulk Density of Soil

The soil textures of selected six farms were determined by the USDA method. The bulk densities of the soils were determined by following the standard methology (Lambe, 1951).

3.3.7 Economics Analysis

For the assessment of production, use of inputs and profitability of non rice crops, a questionnaire survey was conducted on 40 farmers (15 farmers for onion, 10 farmers for garlic and 15 farmers for wheat) including the 6 farmers selected for in- field study. For an assessment of the profitability of the crops, a benefit-cost analysis was carried out based on the data collected from the questionnaire survey.

In this study, the fixed cost such as land rent, taxes and interest on value of land have not been added in the cost, and only variable cost (human labor, land preparation, seeds, fertilizer, processing, irrigation etc.) were taken into consideration.

Chapter Four

Results and Discussion

4.1 Rabi Crop Decision Model

On the basis of the field tests and discussion with the farmers, the developed decision model on whether to grow a Rabi crop or rice is shown in Figure 4.1. Each rectangle in the figure represents a decision, which is guided by a Yes (Y) or a No (N) to an action (represented by an ellipse) or to another decision. The decision to grow a Rabi crop is very much dictated by the harvest time of the preceding Aman (monsoon rice) crop. If the Aman crop is harvested within November, then irrespective of the soil moisture condition, farmers go for a Rabi crop. Past experience has shown that if the monsoon rice can be harvested within November, then the soil moisture is favourable both for tilling and Rabi crop establishment. The farmers have no control over the harvest time (which depend on the transplanting time) of the rainfed Aman crop. The transplantation of the Aman crop can be delayed because of the late advent of the monsoon or inadequate rainfall for land preparation and puddling.

If the Aman crop is harvested within December, then farmers' decision on whether to go for a Rabi crop or not depends upon the soil moisture condition at the time of harvest. The soil moisture is important both for tilling and also for establishment of the crop. If the soil moisture is considered to be adequate then a positive decision is made for Rabi crop. If the farmer's field is situated in the HYV rice block then decision to grow HYV rice also depends upon the economic condition of the farmers as growing of HYV rice requires expensive inputs, otherwise the farmers grow a non-rice crop. If the production of Aman crop is good, the farmers are food secured. This is why, farmers grow Rabi crops instead of rice.

4.1.1 Farmers' Decision Model on selection of Non-rice Crop

Once the farmer has decided that he is going to grow a Rabi crop, then he has to decide about which crop to grow. The decision model about the selection of a non rice crop is shown in the model (Figure 4.2). According to the model, some farmers do not

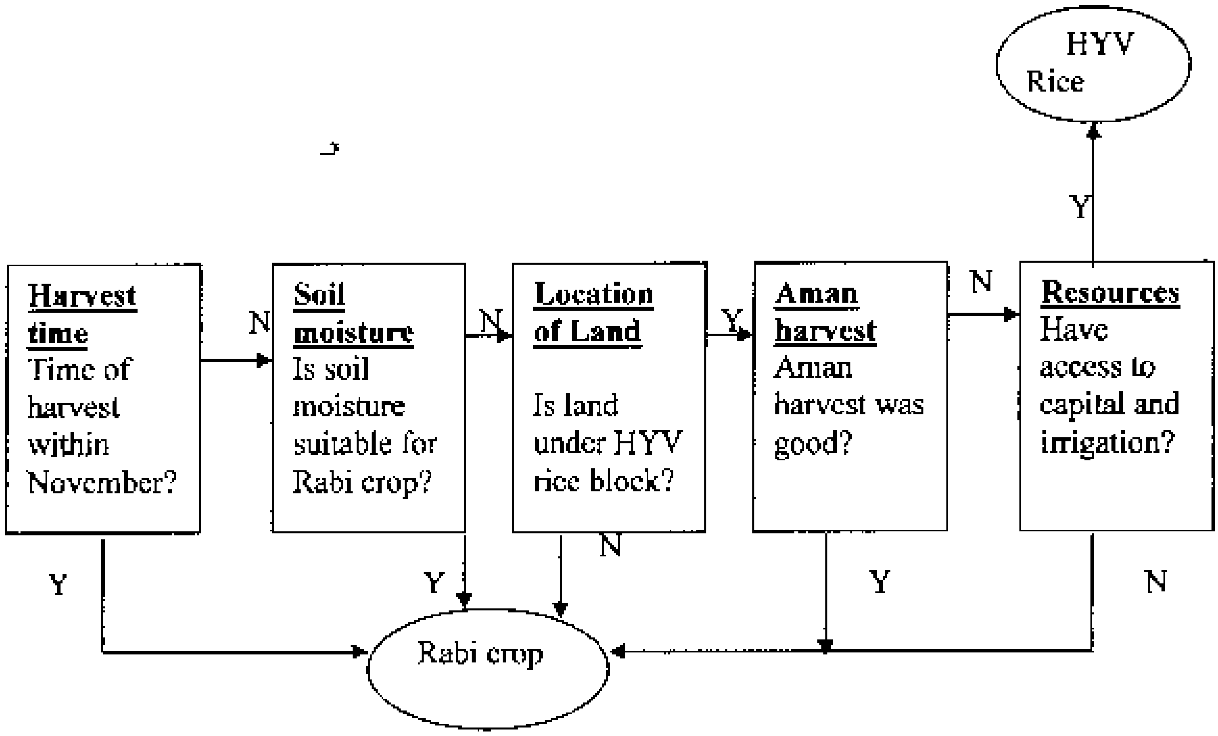


Figure 4.1 Decision model for Rabi crop

cultivate Aman rice because they want to start early in the Rabi season and grow onion/garlic or HYV wheat. Basically, they are owners of high land and they believe that early Rabi crops are more profitable than the Aman rice. If at the beginning of the season, the soil moisture is not suitable for tilling, then farmers decide to grow HYV wheat in the field (after the land became suitable for cultivation). For the farmers whose lands are suitable for tilling, access to capital and irrigation facilities determine the Rabi crops to be grown. The farmers who have no access to capital and irrigation, they decide to grow vegetables and farmers with capital and irrigation grow onion and garlic.

For the farmers who have cultivated Aman rice, the decision about which crop to grow during the Rabi season depends upon a number of factors. If the preceding Aman crop is harvested within November then the farmers with no access to capital and irrigation grow a mixed crop of mustard and lentil. On the other hand, farmers who have access to capital and irrigation grow a mixed crop of onion or garlic. If seeded within 15

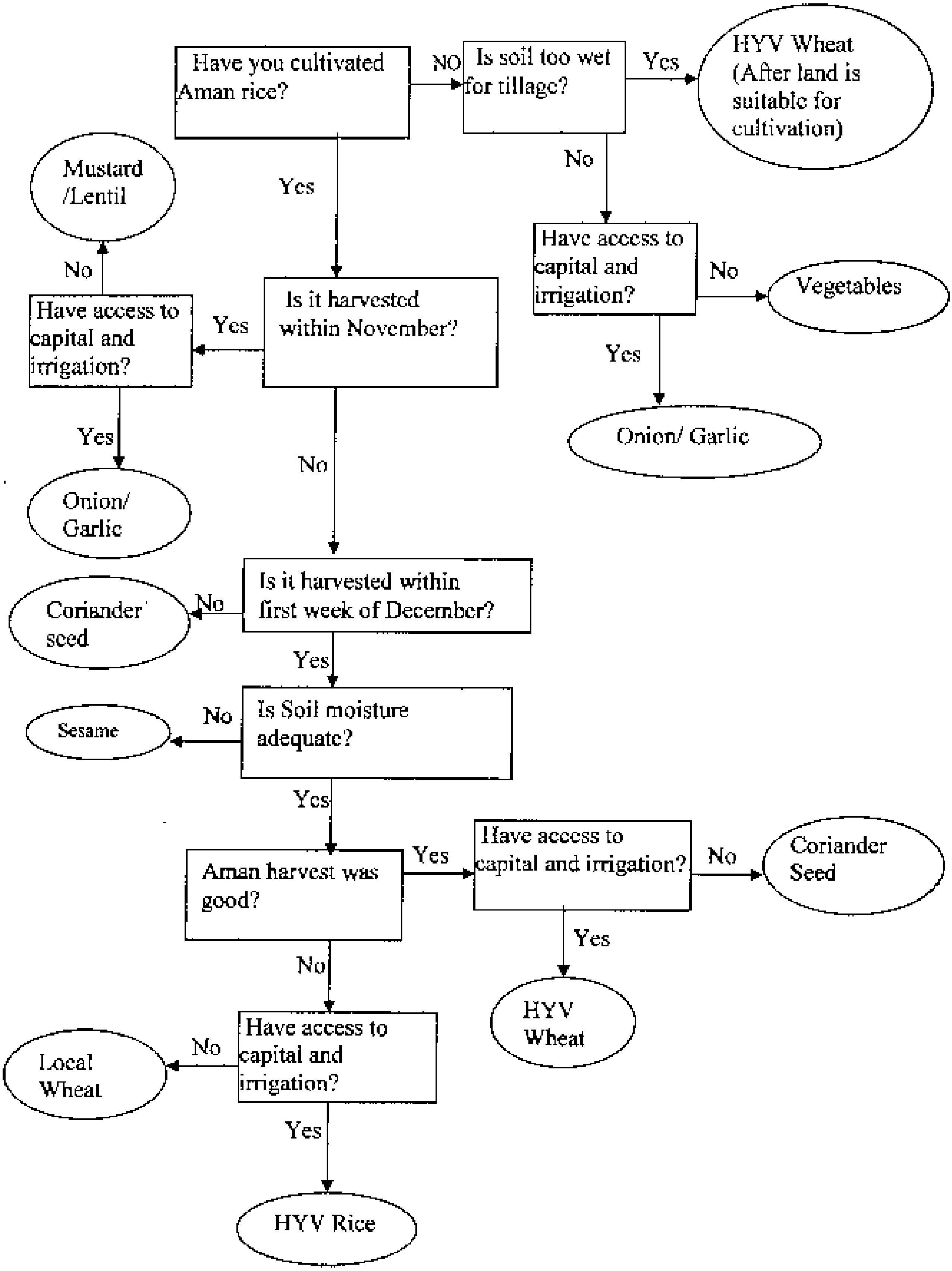


Figure 4.2 Farmers decision model on selection of non-rice crops

November, then those types of crops give high yields and farmers can also obtain more profit from the early harvest. It was observed in the study area that rich farmers prefer to grow onion and garlic and poor farmers prefer to grow lentil, mustard, coriander seed and local wheat because of low input requirements.

If Aman rice is harvested by the farmers within first week of December (which is not the proper time of seeding Rabi crops such as onion and garlic), then the crop selection by the farmers depends upon a number of factors such as available soil moisture, production of Aman, access to capital and irrigation etc. However, if Aman rice is harvested by farmers beyond first week of December, then farmers decide to grow coriander seed because other Rabi crops are not suitable after December. If the soil moisture is not suitable, then the farmers would like to select sesame seeds On the other hand, if the soil moisture is suitable, then with a good harvest of the preceding Aman rice, either HYV wheat or coriander seed is selected by the farmers depending upon the access to capital and irrigation facilities. For the farmers whose Aman harvests were not good, majority of them would like to grow HYV rice As HYV rice requires additional inputs such as fertilizers, irrigation and pesticides, farmers would like to grow HYV rice only if they have access to these inputs Otherwise, they would grow local wheat which does not require these inputs but give low yield

4.2 Water Management and Profitability of Non-Rice Crops as Practiced by the Farmers

It is evident from the preceding non-rice crops decision model that because of profit the farmers want to grow onion, garlic, and wheat even by sacrificing in the preceding Aman rice. On the other hand, for the farmers who have grown Aman rice, their preferred crops are onion, garlic and wheat if the Aman rice was timely harvested and soil moisture was favourable From the discussion with the farmers it was evident that because of favourable soil characteristics and higher profitability, the farmers in the study area prefer to grow onion, garlic and wheat. In the following sections, the water management and profitability of these crops are presented.

4.2.1 Water Management and Profitability of Onion as practiced by the farmers

The water management practices and the profitability of growing onion by two farmers were studied. The total farm area of one farmer (Onion -1) was 0 .093 ha and the other one (Onion-2) was 0.0401 ha. In this study, root zone depth of onions was taken as 30 cm (Kumar et al., 2007). The bulk density of soil of Onion-1 and Onion-2 were 1.26 gm/cm^3 and 1.60 gm/cm^3, respectively. The soil textures of Onion-1 and Onion-2 fields were sandy loam and silty loam, baving specific gravity 2.50 and 2.59, respectively. The onion seeds were sown on 14th November 2008 and onions were harvested on 28th January 2009, that is 76 days after sowing. Both the farmers harvested the onion before the bulbs became fully matured as the price of onion was high at the time of harvest.

4.2.1.1 Assessment of Water Use

Water use by onions was estimated on the basis of the depleted average moisture content in the crop root zone. The contribution of rainfall to the soil moisture was considered in this analysis. It needs to be mentioned that both the farmers did not apply any irrigation in their fields. The soil moisture depletion profiles of the two fields during the crop growth period at different depths of the root zone are sown in the Figures 4.3 and 4.4.

The Figure 4.3 shows that the average moisture content of Onion-1 field was 24% on the day of sowing (14th November. 2008) at 0-15 cm soil profile and it decreased gradually at 15 days interval. The moisture content increased by 3% on an average at 45th day because of rainfall. At 76th day (day of harvesting), the moisture content reached at the lowest point of 12.8% in the same profile. The moisture content of Onion-1 field was 31.2% on the day of sowing at the 15-30 cm soil profile and it gradually decreased at 15 days interval. However, the average moisture content of soil in this profile slightly increased at 45th day due to rainfall. Again, the average moisture content reached the lowest average value of 21.6% at the time of harvest.

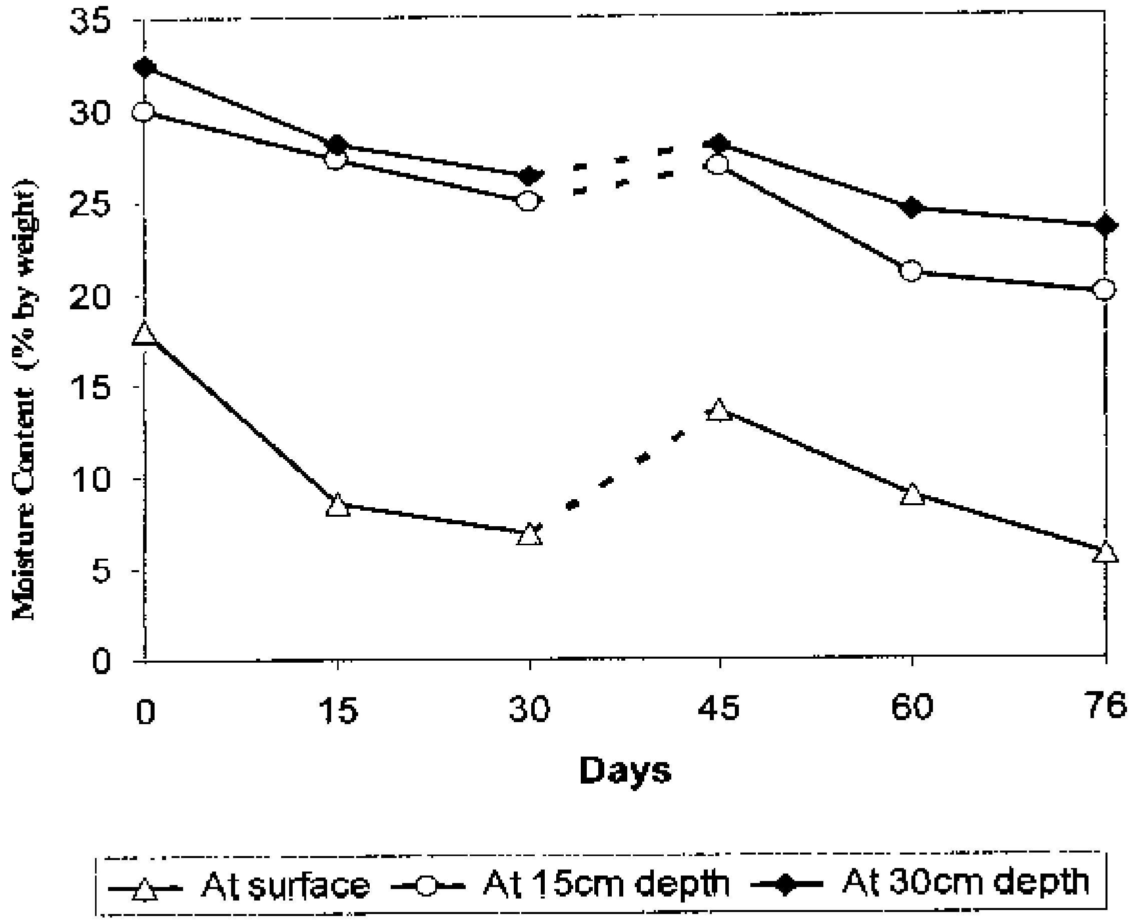


Figure 4.3 Change of moisture content of Onion-1 at 15- day interval.

The Figure 4.4 shows that the average moisture content of Oinion-2 was 24.7% at the day of sowing (14th November, 2008) at the 0-15 cm depth of soil profile and it gradually decreased over the 15 days interval. The moisture contents of Onion-2 increased (average 1.2%) at 45th day because of rainfall. On the 76th day (day of harvesting), the average moisture content reached the lowest value of 13.4%. The average moisture content was 29% on the day of sowing at 15-30 cm depth of soil profile. The average soil moisture content rose slightly on the 45th day due to rainfall. From then on, the average moisture content reduced and it reached at the lowest value of 23.6% at the time of harvest. Comparison of two soil moisture profile of Onions (Figures 4.3 and 4.4) shows that the contribution of rainfall to soil moisture was higher for Onion-1 than Onion-2 although both the soils show similar depletion pattern. Both fields of onions were not same location.

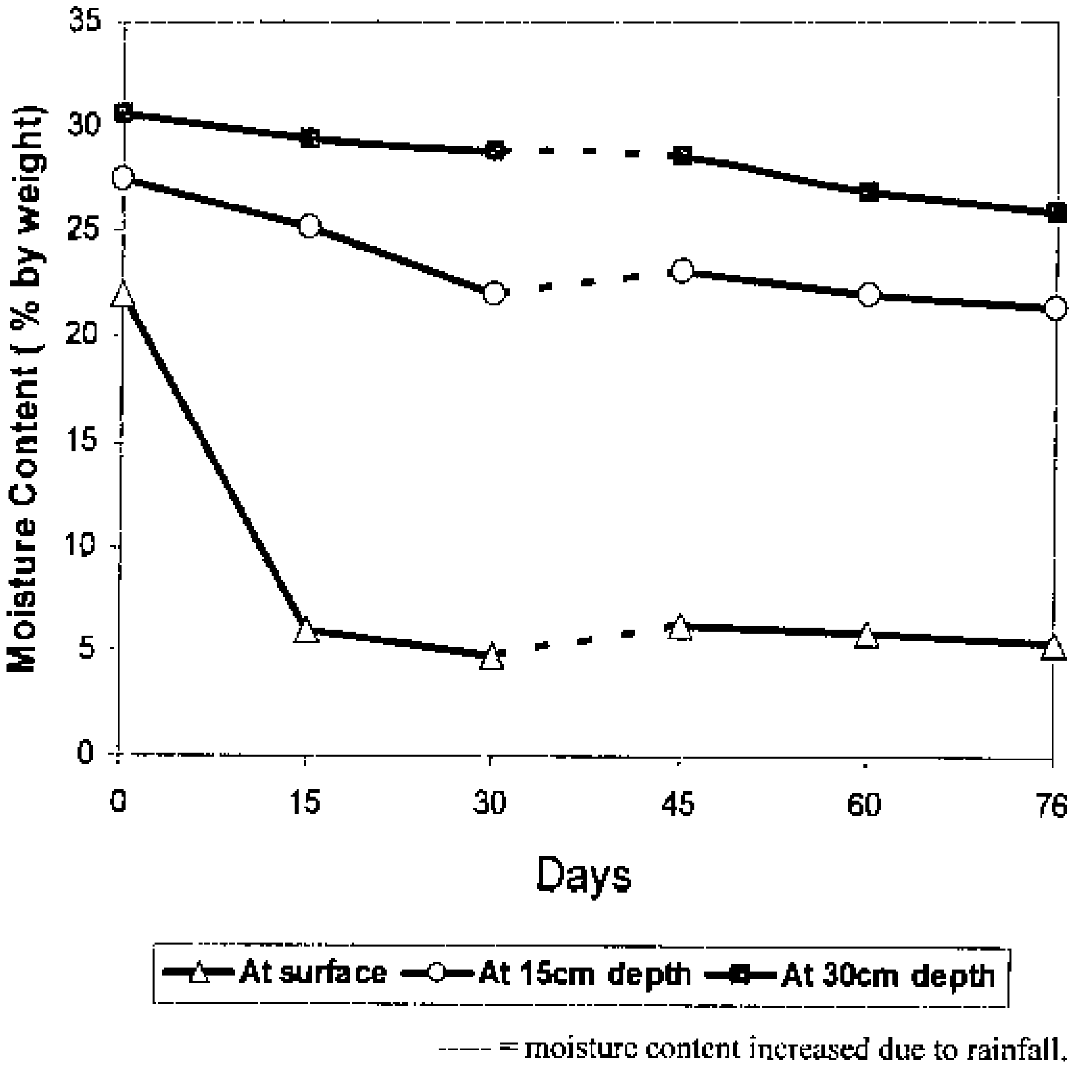


Figure 4.4 Change of moisture content of Onion-2 at 15- day interval.

4.2.1.2 Water and Crop Management

From the soil moisture depletion profiles and using Equation 3.1, the crop water used by onions was estimated. The total crop water use of Onion-1 and Onion-2 were 58 mm and 53.8 mm respectively. The potential crop water requirement of onion was calculated by CROPWAT with average weather data from FAP 4 (Halcrow et al., 1993) and crop coefficient from MPO (Harza, 1984). The potential crop water requirement was calculated as 165.8 mm. The crop water requirement of onion as determined by BARI (Biswas et al., 2003) with 6 irrigations is 279.5 mm. The comparative crop water requirement and the actual crop water use of onion are shown in the Figure 4.5. It is evident from the figure that the actual water use by onion as practiced by the farmers is almost one third of the potential requirement and only about

20% of the water requirement recommended by BARI. The farmers applied no irrigation to these onion fields. It was learnt from the discussion with the farmers that there were many causes for not applying irrigation in the onion field. Firstly, they did not want to increase the production cost of onion because in the previous year, the price of onion was very low. Secondly, the low lift pumps (LLP) with flexible was not available (due to higher price of diesel) for irrigation during the development stage of onion. Finally, the neighbours of the selected farmers were not interested in irrigating their onion fields and the cost of irrigation increases if all the farmers in a block are not irrigating.

The farmers fertilized their field with Urea and the farmer of Onion-2 applied small amount of triple super phosphate (TSP). However, both farmers did not apply any murate of potash (MP) or gypsum to increase the production of onion bulbs. It was revealed from the discussion with the farmers that they had no proper knowledge on application of fertilizers and irrigation and were not aware of BARI recommended input use for onion.

4.2.1.3 Yield

The productions of onion under farmer's practices are shown in Figure 4.6. The production of Onion-2 (6.85 t /ha) was higher than that of production of Onion-1 (6.45 t/ ha) because the owner of Onion-2 applied TSP in his field. Therefore the average production of onion was 6.65 t/ha under farmers practice. In the BARI practice it was 9 t/ha (Biswas et al., 2003) with 6 irrigations (279.5 mm) and a recent Indian research found that the yield can be as high as 19.2 t/ha with total water use of 275.3 mm (Kumar et al., 2007). From the figure it is seen that since the farmers did not follow the BARI recommended irrigation and fertilizer doses, their yield was lowered by almost 2.3 t/ha (almost 26% below the potential yield).

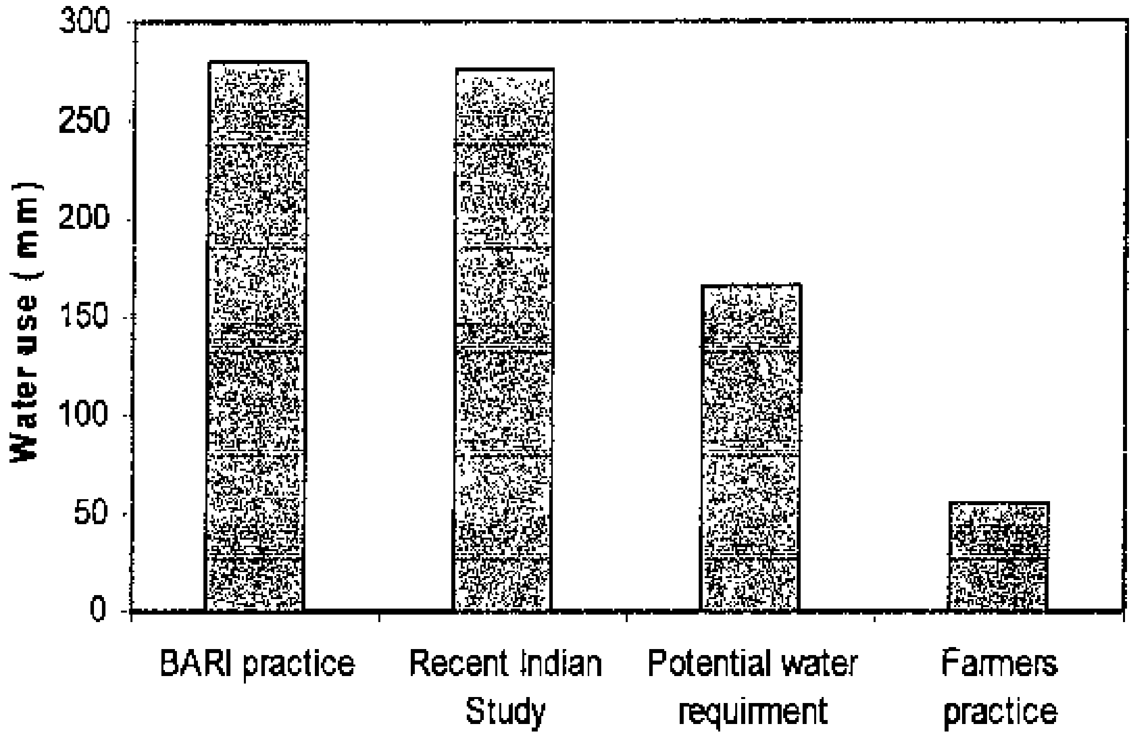


Figure 4.5. Comparative total water use of BARI practice, farmers' practice and potential water requirement of onion

4.2.1.4 Profitability

The benefit-cost ratio (BCR) of growing onion as per farmers' practice is shown in Table 4.1. It is evident from the table that although the farmers had 26% lowered yield compared to that of BARI practice (Figure 4.6) their BCR was almost 21% higher than that of BARI. Earlier harvest and the resulting higher price of onion in this year is the main reason for the higher BCR compared to BARI practice.

4.2.1.5 Survey on Input Use, Yield and Profitability at Farmers' Level

A survey of onion farmers (15 farmers) in the study area was conducted in order to assess their yields, input uses, profitability, and awareness about improved management practices. It was observed from the survey that the average yield at the non-selected farmers' field was 7.53 t/ha compared to 6.65 t/ha at the selected farmers' field.

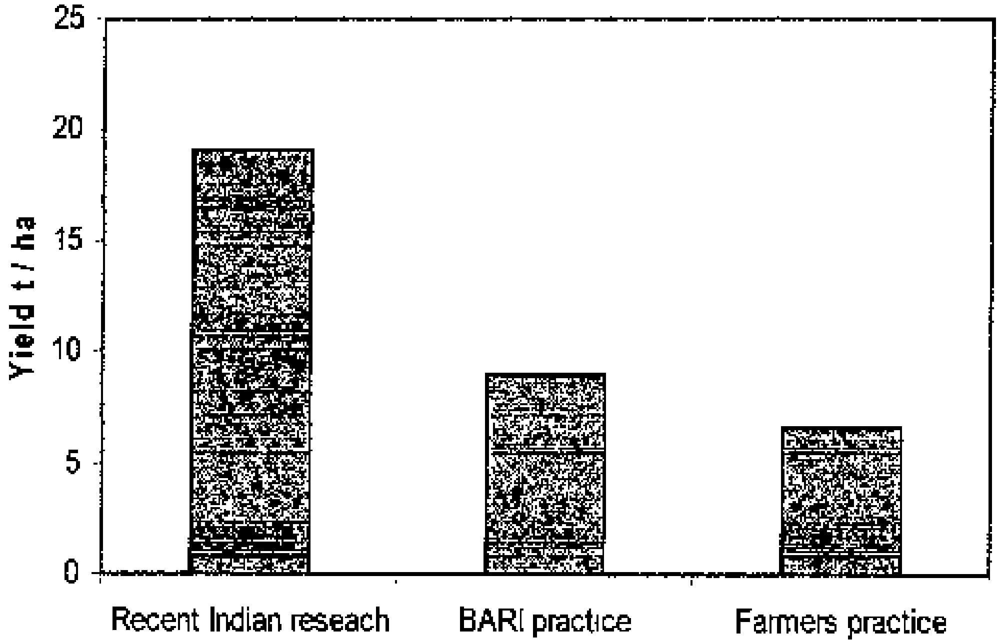


Figure 4.6. Comparative yield of recent Indian research, BARI practice, and farmers' Practice.

The former yield was higher because they harvested 9 days later which allowed the bulbs to mature.

From the farmers' survey, the average benefit-cost ratio (BCR) was 2.39 (Table 4.2) and that for selected farmers, 2.46. Although the production of onion of non-selected farmers was about 11.7% higher but the BCR was almost 3% lower than that of selected farmers. It was observed from the data analysis of non-selected (general) and selected farmers that the main reason for getting less BCR or net return of general farmers was the fall in price of onion at the time of harvest. As mentioned earlier, the general farmers harvested their onion 9 days after the selected farmers and by then price of onion fell by 14.6%.

The awareness of the farmers regarding input use and irrigation (as recommended by BARI) was also ascertained during the survey. It was evident from the survey that the farmers are aware of the impacts of irrigation and input use on yield. But they do not know when and how much of irrigation and other inputs (fertilizer) to apply. They did not apply irrigation because it would increase the cost of production. Because of unawareness, they did not apply a balanced amount of fertilizer (higher amount of Urea and little or no TSP).

Table 4.1 Comparative benefit-cost ratio of BARI practice and farmers practice.

Items		Onion-1 (0.093 ha.)		Onion-2 (0.0401 ha.)		Average Tk./ha
		Amount/Number and Unit	Tk. /ha.	Amount/Number and Unit	Tk. /ha.	
Human labour		10 (@ 120 Tk/ labor)	12903.2	4 (@ 120 Tk/ labor)	11970.07	12436.64
Land preparation		Tk. 600	6451.6	Tk. 260	6483.7	6467.65
Seeds		120 kg (@27.5 Tk./kg)	35483.8	50 kg (@ 27.5 Tk./kg)	34289.27	34886.53
Fertilizers Inputs	Urea	45 kg (@12.5 Tk/kg)	6048.38	20 kg (@12.5 Tk/kg)	6234.41	6141.39
	TSP	-	-	3 kg (@ 70 Tk/ Kg)	5236.90	2618.45
Processing		Tk. 375 (@ Tk. 0.625 /kg)	4032.25	Tk. 165(@ Tk. 0.60 /kg)	4114.71	4073.48
Total variable cost		Tk. 6037.5	64919.35	Tk. 2740	68329.17	66624.26
Flower production		Tk. 450	4838.70	Tk. 220	5486.28	5162.49
Onion Production		600 kg (@ 23.75 Tk/ kg)	153225.80	275 kg (@ 24 Tk/ kg)	164588.5	158907.2
Gross return		Tk. 14700	158064.50	Tk. 6820	170074.8	164069.7
Net return		**Tk. 8662.5**	**93145.16**	**Tk. 4080**	**101745.63**	**97445.4**
Yield		**6.45 t/ha**	**-**	**6.85 t/ha**	**-**	**6.65**
Benefit-cost ratio(Farmer)		-	**2.44**	-	**2.49**	**2.46**
Benefit-cost ratio(BARI)						**1.92**

Source: Field Survey, 2008-2009, Onion selling Price (Farmers) = Tk. 24 / kg, Onion selling Price (BARI) = Tk. 10 /kg

The expected price of onion at the time of harvest is the main determinant for the use of inputs in onion. The farmers are never sure about the price that they would get at the time of harvest. As such they always want to keep the production cost at the minimum. It was evident from the survey that a pre-set price of onion would encourage the farmers to increase the yield of onion with optimum use of inputs.

Table 4.2 Survey on input use, yield and profitability at farmers' level

Items		Amount/Number and Unit (for average land of 0.0794 ha)	Tk. /ha
Human labour		9.5 (@ 120 Tk/ labor)	14357.68
Land preparation		Tk. 550	6926.95
Seeds		106 kg (@27.5 Tk./kg)	36712.84
Fertilizers Inputs	Urea	32.5 kg (@ Tk 12.5 / kg)	5116.50
	Tsp	0.79 kg (@ Tk 70/ kg)	696.47
Processing		Tk. 373.9 (@ Tk. 0.625 /kg)	4709.06
Total variable cost		Tk. 5385.18	67823.42
Flower production		Tk. 650	8186.39
Onion Production		598.3 kg (@ 20.50 Tk/ kg)	154472.92
Gross return		Tk. 12915.15	162659.31
Net return		**7529.97**	**94835.89**
Benefit-cost ratio(Farmer)		-	**2.39**
Onion production		**7.53 t/ha**	

4.2.2 Water Management and Profitability of Garlic as Practiced by the Farmers

The water management practices and the profitability of growing Garlic by two farmers were studied. The total area of one farmer (Garlic -1) was 0.0468 ha and the other one (Garlic-2) was 0.0242 ha. In this study, root zone depth of Garlic was taken as 30 cm (Sarker et al., 2008). The bulk density of soil of Garlic-1 and Garlic-2 were 1.31 gm/cm^3 and 1.34 gm/cm^3, respectively. The soil textures of Garlic-1 and Garlic-2 fields were sandy loam and silty loam, having specific gravity 2.48 and 2.50, respectively. The Garlic seeds were sown on 14th November 2008 and Garlic were harvested on 6th March 2009, that is 113 days after sowing.

4.2.2.1 Assessment of Water Use

Water use by garlic was estimated on the basis of the depleted average moisture content in the crop root zone. The contribution of rainfall to the soil moisture was considered in this analysis. It needs to be mentioned that the owner of Garlic-2 applied one irrigation in his field. The soil moisture depletion profiles of the two fields during the crop growth period at different depths of the root zone are sown in the Figures 4.7 and 4.8.

The Figure 4.7 shows that the average moisture of Garlic-1 was 21% on the day of sowing (14th November, 2008) at the 0-15 cm soil profile and it gradually decreased at 15 days interval. The moisture content increased (average 2.2%) at 45th day because of rainfall. At 113th day (day of harvesting), the moisture content reached at the lowest point of 8.4% in the same profile. The moisture of Garlic-1 was 26.4% on the day of sowing at the 15-30 cm soil profile and it gradually fell over the 15 days interval. However, the average moisture content in this profile slightly rose at 45th day due to rainfall. Again, the average moisture content reached at the lowest average value of 15.3% at the time of harvest.

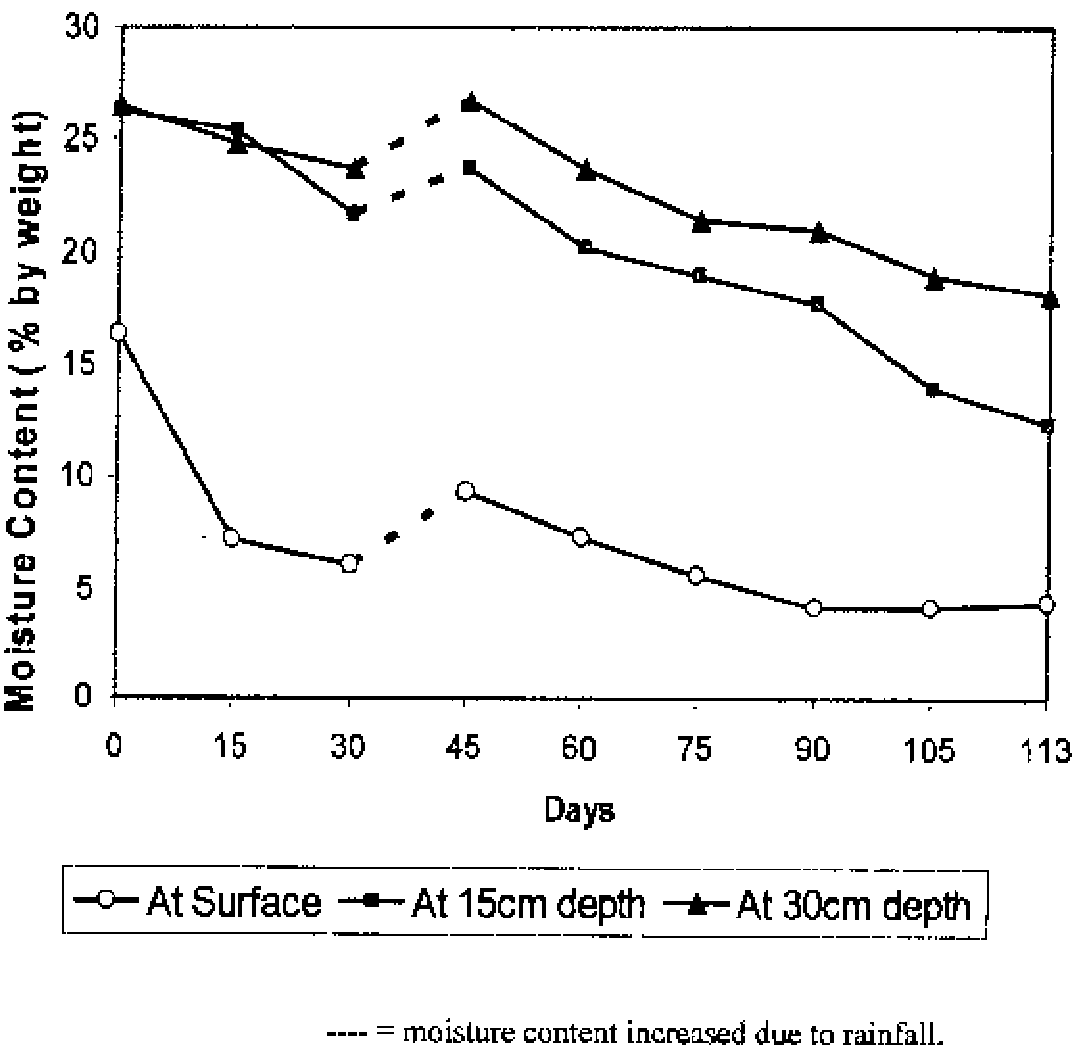


Figure 4.7 Change of moisture content of Garlic-1 at 15- day interval.

The Figure 4.8 shows that the average moisture content of Garlic-2 was 26.5% at the day of sowing (14th November, 2008) at the 0-15 cm depth of soil profile and it gradually decreased over the 15 days interval. The moisture contents of Garlic-2 rapidly increased (average 5.8%) at 45th day because of rainfall and irrigation (farmer applied one irrigation one day before rain). On the 113th day (day of harvesting), the average moisture content reached the lowest value of 10%. The average moisture content was 28.8% on the day of sowing at 15-30 cm depth of soil profile. The average moisture content rose sharply on the 45th day due to rainfall and irrigation. From then on, the average moisture content reduced and it reached at the lowest value of 19.6% at the time of harvest. Comparison of two soil moisture profile of Garlics (Figures 4.7 and 4.8) shows that the soil moisture was higher for Garlic-2 than Garlic-1 due to one extra irrigation in Garlic-2, as a result both the soils show different depletion pattern.

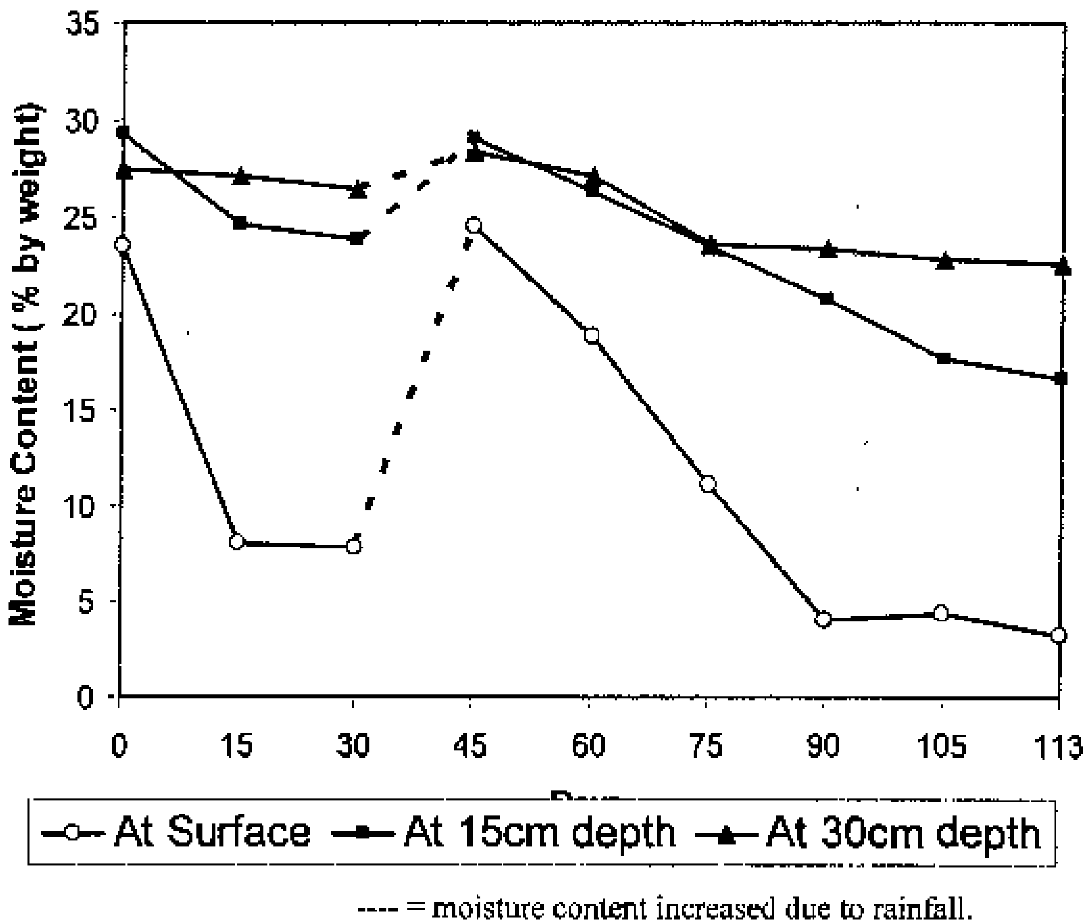


Figure 4.8 Change of moisture content of Garlic-2 at 15- day interval.

4.2.2.2 Water and Crop Management

From the soil moisture depletion profiles and using Equation 3.1, the crop water used by garlic was estimated. The total crop water use of Garlic-1 and Garlic-2 were 65.8 mm and 82.3 mm respectively. The potential crop water requirement of garlic was calculated by CROPWAT with average weather data of FAP 4 (Halcrow et al., 1993) and crop coefficient from MPO (Harza, 1984). The potential crop water requirement was calculated as 276.2 mm. The crop water requirement of garlic as determined by BARI (Sarkar et al., 2008) with 4 irrigations was 261 mm. The comparative crop water requirements and the actual crop water use of garlic are shown in the Figure 4.9. It is evident from the figure that the actual water use by garlic as practiced by the farmers is almost one fourth of the potential requirement and only about 28% of the water requirement recommended by BARI. It was learnt from the discussion with the farmers that there were many causes for not applying proper irrigation in the garlic field. The farmers did not want to increase the production cost of garlic because of higher cost of irrigation due to higher price of diesel. Moreover, the application of irrigation encourages weed growth and increases the cost of weeding.

The farmers fertilized their field with only Urea. However, both selected farmers did not apply any triple super phosphate (TSP), murate of potash (MP) or gypsum that are used to increase the production of garlic bulbs. The price of all fertilizers other than Urea was very high during the last season. It was revealed from the discussion with the farmers that they have no proper knowledge on application of fertilizers and irrigation and are not aware of BARI recommended input use for garlic.

4.2.2.3 Yield

The productions of garlic under farmers' practices are shown in Figure 4.10. The production of Garlic-2 (0.99 t /ha) was higher than that of Garlic-1 (0.85 t / ha) because the owner of Garlic-2 applied one irrigation in his field. Therefore the average production of garlic was 0.92 t/ha under farmers' practice. In the BARI practice the yield was 4.92 t/ha (Sarkar et al., 2008) with 4 irrigations. From the figure it can be seen that as the farmers did not follow the BARI recommended irrigation and fertilizer as inputs, their yield was lowered by almost 4 t/ha (almost 81% below the potential yield).

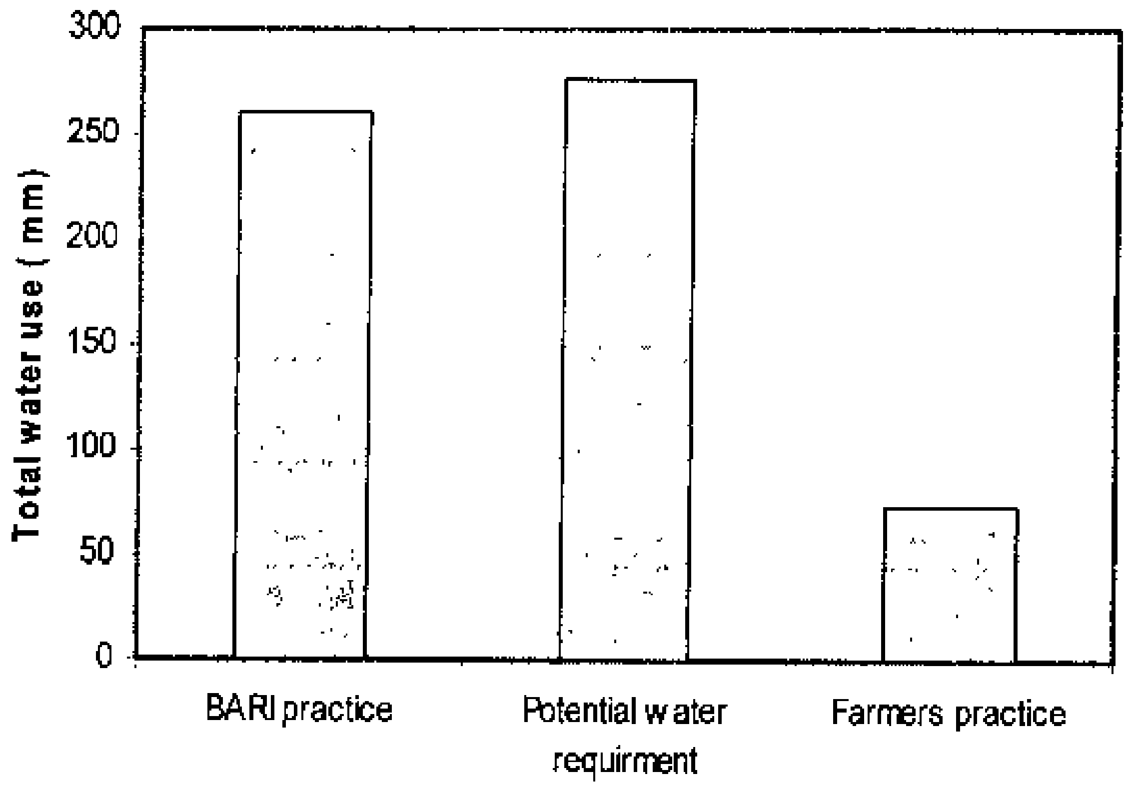


Figure 4.9. Comparative total water use of BARI practice, farmers' practice and potential water requirement of garlic.

4.2.2.4 Profitability

The benefit-cost ratio (BCR) of growing garlic as per farmers' practice is shown in Table 4.3. It is evident from the table that as the farmers had 81% lowered yield compared to BARI practice (Figure 4.10) their BCR was almost 70% lower than that of BARI. Non application of proper irrigation, fertilizer and lower price of garlic in this year are the main reasons for the lower BCR compared to BARI practice.

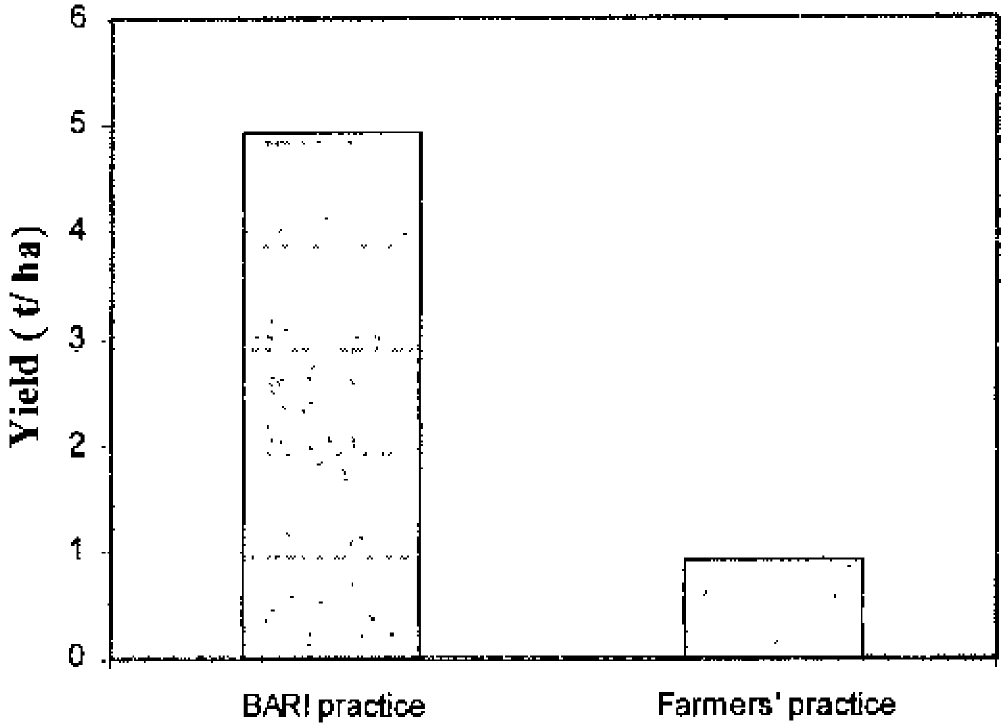


Figure 4.10. Comparative yields of BARI practice and Farmers' practice.

4.2.2.5 Survey on Input Use, Yield and Profitability at Farmers' Level

A survey of garlic producing farmers (10 farmers) in the study area was conducted in order to assess their yield, input uses, profitability, and awareness about improved management. It was observed from the survey that the general farmers' average yield was 1.1 t/ha compared to 0.92 t/ha for the selected farmers. The general farmers yield was higher because they used TSP (almost 17 kg/ha) and selected farmers did not apply any fertilizer except Urea (Table 4.3 & 4.4).

From the farmers' survey the average benefit-cost ratio (BCR) was found 0.74 (Table 4.4) and that for selected farmers that was 0.65. For both categories of farmers, garlic production was a loss in this year. The production of garlic of general farmers was higher and also the BCR was almost 12% higher than that of selected farmers. It was observed from the data analysis of general and selected farmers that the main reason for getting high BCR or net return of general farmers was due to higher yield of garlic produced by general farmers (due to use of small amount of TSP in their fields).

Table 4.3. Comparative benefit-cost ratio of BARI practice and farmers' practice.

Items	Garlic-1 (0 .0468 ha)		Garlic-2 (0.0242 ha.)		Average Tk/ha
	Amount/Number and Unit	Tk /ha	Amount/Number and Unit	Tk /ha	
Human labour	4 (@ 120 Tk/ labor)	10256.41	3 (@ 120 Tk/ labor)	14876.3	12566.36
Land preparation	Tk. 300	6410.26	Tk. 150	6198.3	6304.28
Seeds	25 kg (@ 20 Tk./kg)	10683.76	15 kg (@ 20 Tk./kg)	12396.7	11540.23
Urea	16 kg (@12.5 Tk/kg)	4006.41	12 kg (@12.5 Tk/kg)	6198.3	5102.355
Processing	Tk. 20.5	438.03	Tk. 11	454.54	446.285
Irrigation	-	-	Tk. 100	4132.23	2066.115
Total variable cost	Tk. 1487.99	31794.87	Tk. 1071	44256.19	38025.53
Garlic Production	40 kg (@ 26.25 Tk/ kg)	22435.9	24 kg (@ 26.50 Tk/ kg)	26280.9	24358.4
Gross return	**Tk. 1050**	**22435.9**	**Tk. 636**	**26280.9**	24358.4
Net return	**-437.99**	**-9358.97**	**Tk. -435**	**-17975.2**	**-13667.1**
Yield	**0.85 t/ha**		**0.99 t/ha**		**0.92**
Benefit-cost ratio(Farmer)	-	**0.70**	-	**0.59**	**0.65**
Benefit-cost ratio(BARI)					**2.20**

The awareness of the farmers regarding input use and irrigation (as recommended by BARI) was also ascertained during the survey. It was evident from the survey that the farmers are aware of the impacts of irrigation and input use on yield. But they do not know when and how much of irrigation and other inputs (fertilizer) to apply. They did not apply irrigation because it would increase the cost of production (e.g. the price of diesel was high). Because of unawareness, they did not apply balanced amount of fertilizers (higher amount of Urea and little or no TSP).

The expected price of garlic and the time of harvest is the main determinant for the use of inputs in garlic. The farmers are never sure about the price that they would get at the time of harvest. As such they always want to keep the production cost at the minimum.

It was evident from the survey that a pre-set price of garlic would encourage the farmers to increase the yield of garlic with optimum use of inputs.

Table 4.4 Survey on input use, yield and profitability at farmers' level

Items		Amount/Number and Unit (for average land of 0.07233 ha)	Tk. /ha.
Human labour		6.37 (@ 120 Tk/ labor)	10576.52
Land preparation		Tk. 553.75	7655.88
Seeds		44.5 kg (@ 20 Tk./kg)	12304.71
Fertilizers Inputs	Urea	35.75 kg (@ 12.5 Tk/Kg)	6178.28
	Tsp	1.25 kg (@ 70 Tk/Kg)	1209.73
Processing		Tk. 54 (@ Tk. 0.50 /kg)	746.5782
Total variable cost		Tk. 2780.6	38443.27
Garlic Production		80 kg (@ 26 Tk/ kg)	28757.0
Gross return		Tk. 2080	28757.0
Net return		**Tk. -744**	**-10286.18**
Benefit-cost ratio(Farmer)		-	**0.74**
Yield		**1.1 t/ha**	

4.2.3 Water Management and Profitability of Wheat as Practiced by the Farmers

The water management practices and the profitability of growing wheat by two farmers were studied. The total area of one farmer (Wheat -1) was 0.0667 ha and the other one (Wheat-2) was 0.0647 ha. In this study, root zone depth of wheat was taken as 50 cm (Laghari et al, 2008). The bulk density of soil of Wheat-1 and Wheat-2 were 1.20 gm/cm^3 and 1.22 gm/cm^3, respectively. The soil textures of Wheat-1 and Wheat-2 fields were loam and sandy loam, having specific gravity 2.55 and 2.54, respectively. The wheat seeds were sown on 14th November 2008 and wheat was harvested on 8th March 2009 that is 115 days after sowing.

4.2.3.1 Assessment of water use

Water use by wheat was estimated on the basis of the depleted average moisture content in the crop root zone. The contribution of rainfall to the soil moisture was considered in this analysis. It needs to be mentioned that the both farmers did not apply any irrigation in their fields. The soil moisture depletion profiles of the two fields during the crop growth period at different depths of the root zone are sown in the Figures 4.11 and 4.12.

The Figure 4.11 shows that the average moisture of Wheat-1 was 26.1% on the day of sowing (14th November, 2008) at the 0-25 cm soil profile and it gradually decreased at 15 days interval. The moisture content increased (average 1.2%) at 45th day because of rainfall. At 115th day (day of harvesting), the moisture content reached at the lowest point of 8.7% in the same profile. The moisture of Wheat-1 was 31.2% on the day of sowing at the 25-50 cm soil profile and it gradually fell over the 15 days interval. However, the average moisture content in this profile slightly rose at 45th day due to rainfall. Again, the average moisture content reached at the lowest average value of 16.0% at the time of harvest.

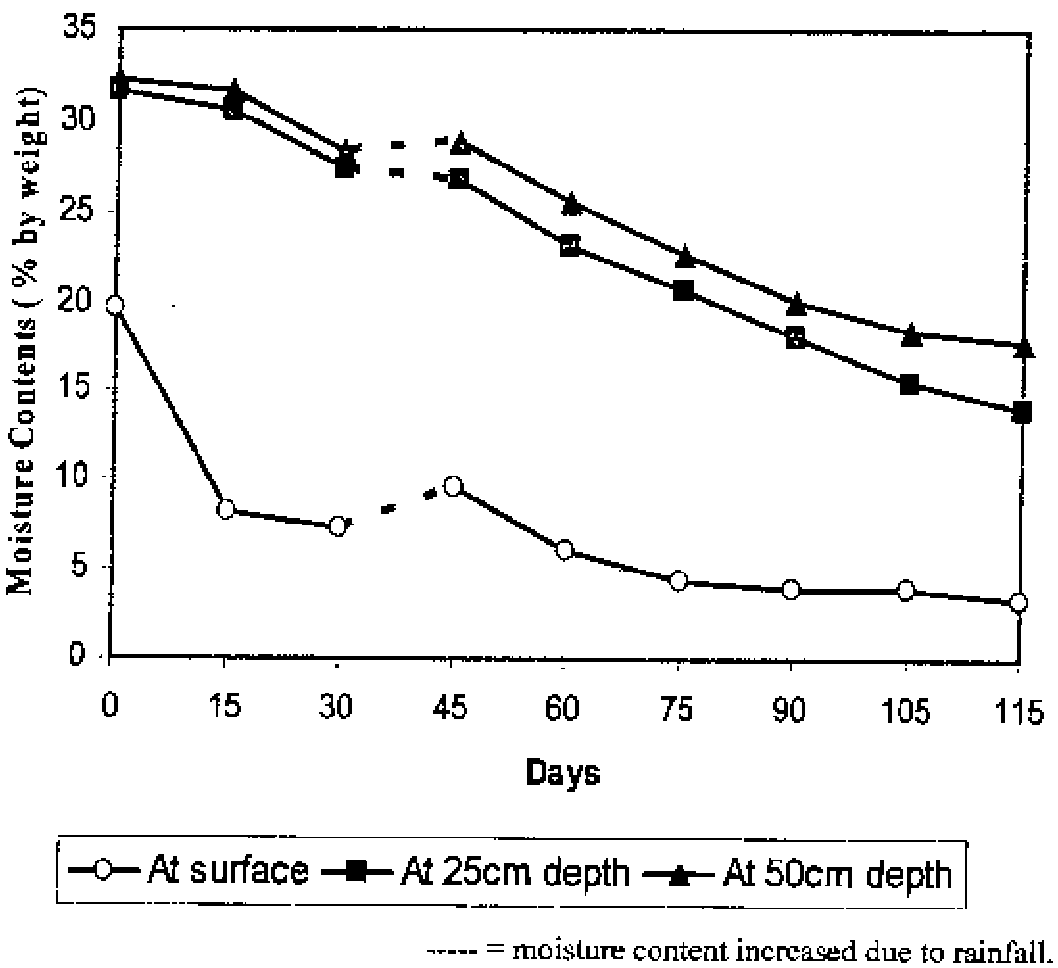
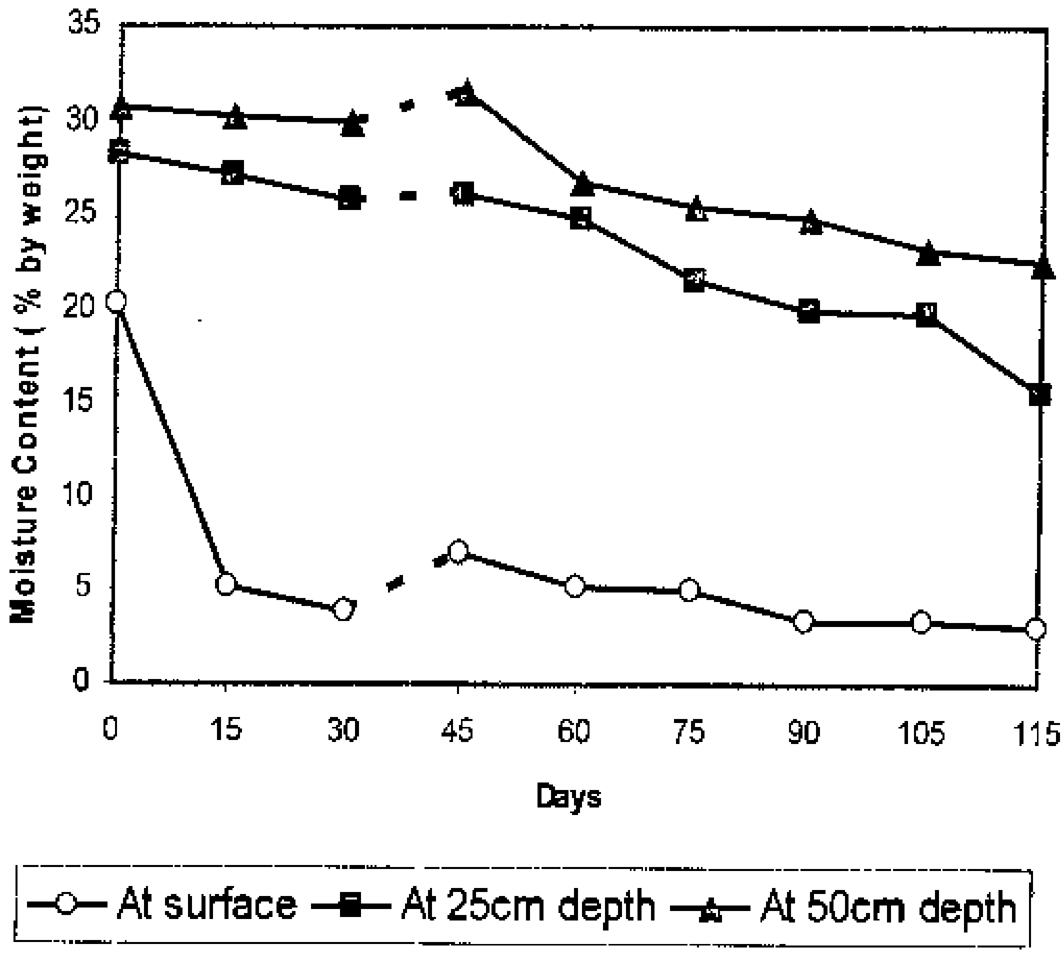


Figure 4.11 Change of moisture content of Wheat-1 at 15- day interval.

The Figure 4.12 shows that the average moisture content of Wheat-2 was 24.9% at the day of sowing (14th November, 2008) at the 0-25 cm depth of soil profile and it gradually decreased over the 15 days interval. The moisture contents of Wheat-2 increased (average 1.5%) at 45th day because of rainfall. On the 115th day (day of harvesting), the average moisture content reached the lowest value of 9.3%. The average moisture content was 30.6% on the day of sowing at 25-50 cm depth of soil profile. The average moisture content rose slightly on the 45th day due to rainfall. From then on, the average moisture content reduced and it reached at the lowest value of 19.2% at the time harvest. Comparison of two soil moisture profile of wheat (Figures 4.11 and 4.12) shows that the contribution of rainfall to soil moisture was slightly higher for Wheat-1 than Wheat-2 (at 0-25 cm). Both fields of wheat were not same location.



----- = moisture content increased due to rainfall.

Figure 4.12 Change of moisture content of Wheat-2 at 15- day interval.

4.2.3.2 Water and Crop Management

From the soil moisture depletion profiles and using Equation 3.1, the crop water used by wheat was estimated. The total crop water use of Wheat-1 and Wheat-2 were 119.2 mm and 96.30 mm respectively. The potential crop water requirement of wheat was calculated by CROPWAT with average weather data of FAP 4 (Halcrow et al., 1993) and crop coefficient from MPO (Harza, 1984). The potential crop water requirement was calculated as 258.4 mm. The crop water requirement of wheat as determined by BARI (Sarkar et al., 2008) with 3 irrigations was 291 mm. The comparative crop water requirements and the actual crop water use of wheat are shown in the Figure 4.13. It is evident from the figure that the actual water use by wheat as practiced by the farmers is almost two-fifths of the potential requirement and only about 37% of the water requirement recommended by BARI. Both the farmers did not apply any irrigation water in their wheat fields. It was learnt from the discussion with the farmers that there were many causes for not applying irrigation in the wheat field. The farmers did not want to increase the production cost of wheat because of higher cost of irrigation due to higher price of diesel. Finally, the neighbors of the selected farmers were not interested to irrigate their wheat fields and the cost of irrigation increases if all the farmers in a block are not irrigating.

The farmers fertilized their field with only Urea. However, both farmers did not apply any triple super phosphate (TSP), murate of potash (MP) or gypsum that is used to increase the production of wheat. It was revealed from the discussion with the farmers that they have no proper knowledge on application of fertilizers and irrigation and are not aware of BARI recommended input use in wheat.

4.2.3.3 Yield

The production of wheat under farmers' practices is shown in Figure 4.14. The production of Wheat-2 (1.7 t/ ha) was lower than that of production of Wheat-1 (2.1 t/ ha) may be because of seed variety (Wheat-1 was Kanchon and Wheat-2 was Sonalika, DAE, 1992). Therefore the average production of wheat was 1.9 t/ha under farmers' practice. In the BARI practice the yield was 4.1 t/ha (cv. Kanchon, Sarkar et al., 2008) with 3 irrigations.

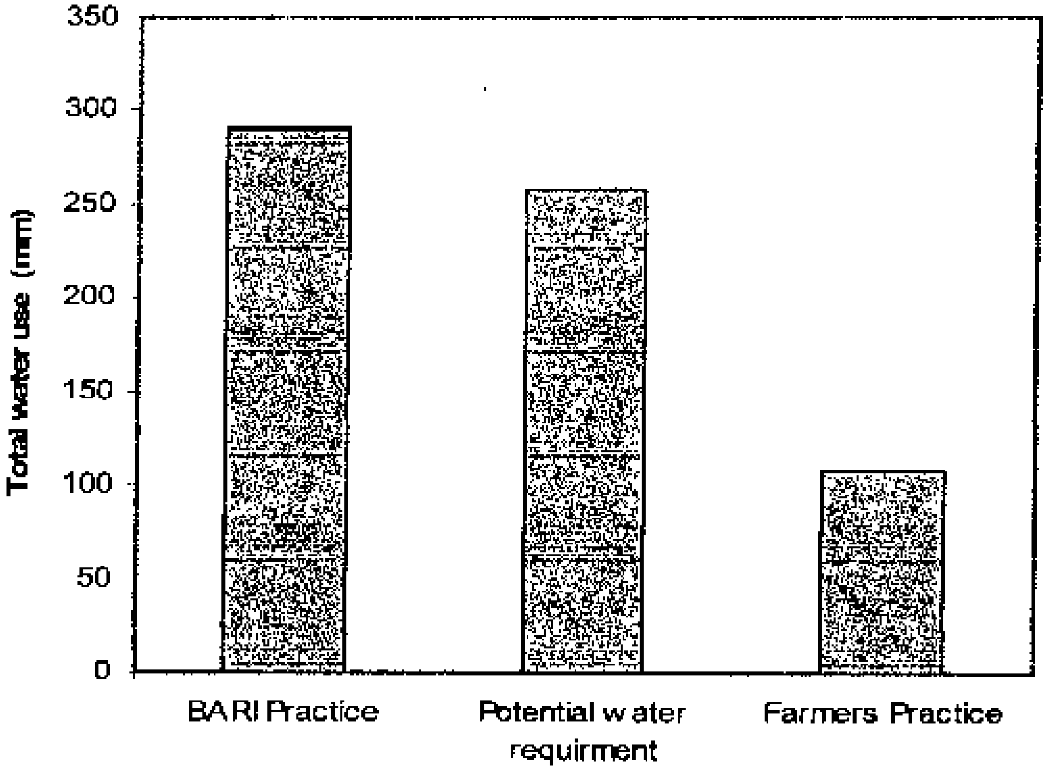


Figure 4.13. Comparative total water use of BARI practice, farmers' practice and potential water requirement of wheat.

From the figure it can be seen that as the farmers did not follow the BARI recommended irrigation and fertilizer as inputs, their yield was lowered by almost 2 t/ha (almost 53% below the potential yield).

4.2.3.4 Profitability

The benefit-cost ratio (BCR) of growing wheat as per farmers practice is shown in Table 4.5. It is evident from the table that as the farmers had 53% lowered yield compared to BARI (Figure 4.14) their BCR was almost 60% lower than that of BARI. Non applications of proper irrigation, fertilizer and lower price of wheat in this year are the main reasons for the lower BCR compared to BARI practice.

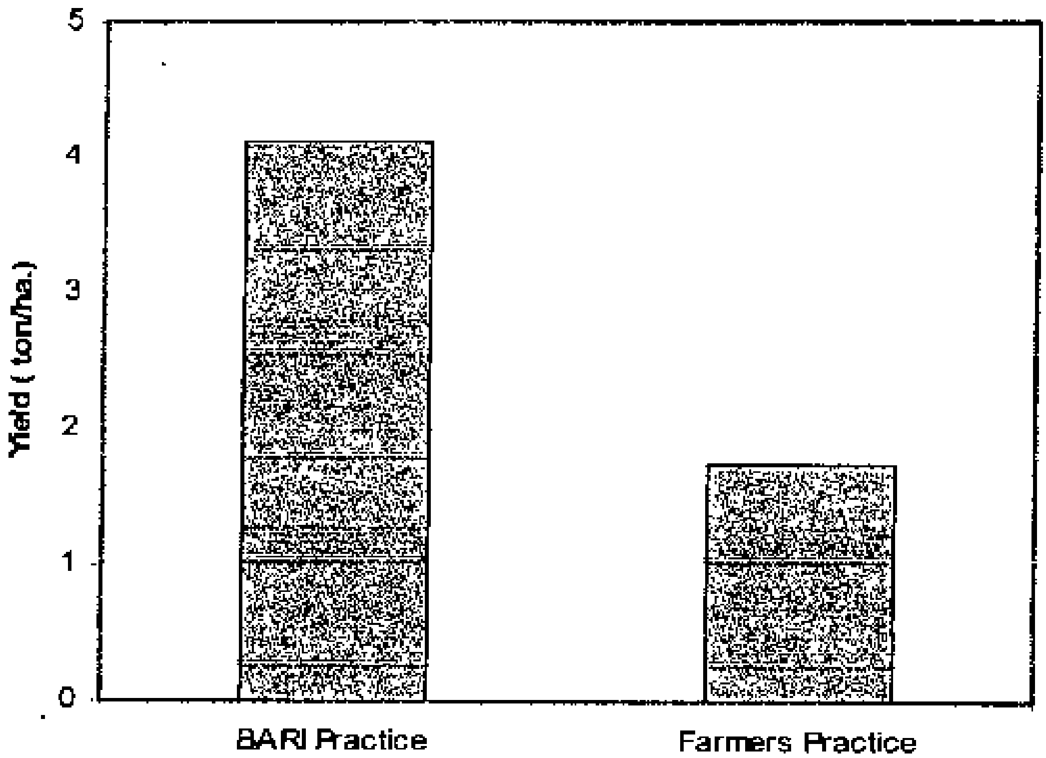


Figure 4.14. Comparative yield of BARI practice and Farmers' practice.

4.2.3.5 Survey on Input Use, Yield and Profitability at Farmers' Level

A survey of wheat producing farmers (15 farmers) in the study area was conducted in order to assess their yield, input uses, profitability, and awareness about improved management. It was observed from the survey that the general farmers' average yield was 1.8 t/ha compared to 1.9 t/ha for the selected farmers. The general yield was lowered than that of selected farmers because some farmers cultivated local wheat.

From the farmers' survey, the average benefit-cost ratio (BCR) was 1.21 (Table 4.6) and that for selected farmers that was 1.33. The yield of wheat of general farmers was lower and also the BCR was almost 9% lower than that of selected farmers. It was observed from the data analysis of general and selected farmers that the main reason for getting less BCR or net return of general farmers was that the yield of general farmers was slightly lower.

Table 4.5 Comparative benefit-cost ratio of BARI practice and farmers' practice.

Items		Wheat-01(0.066 ha)		Wheat-02 (0.0647 ha.)		Average
		Amount/Number and Unit	Tk. /ha.	Amount/Number and Unit	Tk. /ha.	
Human labour		4 (@ 120 Tk/ labour)	7272.72	2 (@ 120 Tk/ labor)	3709.42	5491.0
Land preparation		Tk. 345	5227.27	Tk. 280	4327.66	4777.50
Seeds		9 kg (@ 35 Tk./kg)	4772.72	9 kg (@ 35 Tk./kg)	4868.62	4820.70
Fertilizer inputs	Urea	25 kg (@12.5 Tk/kg)	4734.84	20 kg (@12.5 Tk/kg)	4517.125	5102.40
Processing		Tk. 150(@ Tk. 1.07/kg)	2272.72	Tk. 130(@ Tk. 1.18/kg)	2009.27	2140.9
Total variable cost		Tk. 1487.99	24480.27	Tk. 1243.17	19214.38	21847.30
Wheat Production		140 kg (@ 15 Tk/ kg)	31818.18	110 kg (@ 15.5 Tk/ kg)	26352.39	29085.30
Gross return		Tk. 2100	31818.18	Tk. 1705	26352.39	29085.30
Net return		**484.30**	**7337.91**	**Tk. 444.99**	**7138.01**	**7237.96**
Yield		**2.1 t/ha**		**1.7 t/ha**		**1.9**
Benefit-cost ratio(Farmer)		-	**1.30**	-	**1.37**	**1.33**
Benefit-cost ratio (BARI)		-	-	-	-	**3.35**

The awareness of the farmers regarding input use and irrigation (as recommended by BARI) was also ascertained during the survey. It was evident from the survey that the farmers are aware of the impacts of irrigation and input use on yield. But they do not know when and how much of irrigation and other inputs (fertilizer) to apply. They did not apply irrigation because of higher cost of irrigation due to higher price of diesel. Because of unawareness, they did not apply a balanced amount of fertilizer (higher amount of Urea and no TSP).

The expected price of wheat at the time of harvest is the main determinant for the use of inputs in wheat. The farmers are never sure about the price that they would get at the time of harvest. It was evident from the survey that a pre-set price of wheat would encourage the farmers to increase the yield of wheat with optimum use of inputs.

Table 4.6 Survey on input use, yield and profitability at farmers' level

Items		Amount/Number and Unit (for average land of 0.0818 ha)	Tk. /ha.
Human labour		4.30 (@ 120 Tk/ labor)	6308.068
Land preparation		Tk. 488	5965.77
Seeds		10.6 kg (@ 35 Tk./kg)	4535.452
Fertilizers Inputs	Urea	21.8 kg(@ 12.5 Tk/Kg)	3331.296
	Tsp	1.30 kg(@ 70 Tk/Kg)	1112.469
Processing		Tk. 150 (@ Tk. 0.98 /kg)	1833.741
Total variable cost		Tk. 1888.5	23086.8
Wheat Production		152.5 kg (@ 15 Tk/ kg)	27964.55
Gross return		Tk. 2287.5	27964.55
Net return		**Tk. 399**	**4877.751**
Benefit-cost ratio(Farmer)		**1.21**	**1.21**
Yield		**1.8 t/ha**	

4.3 Discussion on farmers' Crop Management Practices

From the results on water and fertilizer management practices presented in the preceding sections, it is evident that the farmers in the study area do not follow the BARI recommended level of irrigation and fertilizer (Table 4.7). The farmers are aware of the impacts of irrigation and input use on yield but they do not know when and how much of irrigation and fertilizer to apply. Because of unawareness, they also do not apply a balanced amount of fertilizer (almost four times the amount of Urea and little or no TSP and other fertilizer as shown in Table 4.7). As a result, the farmers do not obtain the potential yields of these crops.

As mentioned earlier, the expected price of the crop at the time harvest is the main determinant for the use of inputs in crops. The price the farmers got in the immediate past year strongly influences their expected current price. A higher price in the immediate past year encourages the use of more inputs with the expectation of a higher yield and higher profit.

From the discussion with the farmers it was apparent that in case of onion, the price was very low (Tk. 6/kg) last year and hence this year the farmers were not interested to invest on inputs like irrigation and fertilizer. But the price of onion was high (almost Tk 20-24 /kg) this year and onion production turned out to be very profitable even though the yield was below the average (average yield of 8.42 t/ha and this year yield of 7.53 t/ha). In case of both garlic and wheat, the prices were high in the preceding year. The farmers were willing to invest on inputs this year but the high price of both diesel and fertilizer (except Urea) was a deterrent for their optimal use. The price of garlic was slightly higher this year compared to last year (past year was Tk. 22-24 /kg and this year Tk. 26 /kg) but as the yields were low (average yield of 3.6 t/ha and this year yield almost 1 t/ha), garlic production turned out to be a loss. On the other hand, wheat price is low this year compared to last year (last year's price was Tk. 25 /kg and this year's price is Tk. 15 /kg). As such, wheat production is marginally profitable (because the yield did not significantly fall, as the average yield is 1.9 t/ha and this year's yield is 1.8 t/ha).

The farmers were asked about why instead of growing Rabi crops like garlic and wheat (which are not very profitable) they do not grow Boro rice. It was evident that Boro production requires huge amount of cash money (Tables 4.4, 4.6 & 4.8) because of high inputs requirements (both for irrigation and fertilizer) and is also not very profitable. As their lands are suitable for Rabi crops and these crops require less inputs and cash money (compared to Boro rice) they prefer to grow Rabi crops. Moreover, immediately after the harvest of Rabi crops they can grow Aus rice (which is a rainfed crop) to make up for their cereal requirements and Aus rice requires much less inputs compared to Boro rice.

Table 4.7 Comparison between farmer's inputs and BARI recommended inputs.

Name of crops	Inputs Name	BARI recommendation Kg/ ha	Farmers' practice Kg/ha
Onion (Biswas et al., 2003)	Urea	90	463.9
	TSP	75	41.9
	MP	120	-
	Gypsum	18	-
	Irrigation	6 at 10 days interval	-
	Production	9 t/ha	7 .5 t/ha
Garlic (Sarkar et al., 2008)	Urea	150	444.48
	TSP	120	17
	MP	75	-
	Gypsum	30	-
	Irrigation	at 15 days interval	-
	Production	4.92 t/ha	1.1 t/ha
Wheat (Sarkar et al., 2008)	Urea	100	318.13
	TSP	60	15
	MP	40	-
	Gypsum	20	-
	Irrigation	3 (21, 45 & 65 DAS)	-
	Production	4.1 t/ha	1.8 t/ha

DAS: days after seedling

Table 4.8 Yield and Profitability of HYV Rice in Rabi Season (2008-2009).

Items	Amount/Number (for average land 0.17023 ha)	Tk/ha
Land preparation ((Tk))	1083.3	6363.9
Irrigation (Tk)	3333.3	19581.3
Seeds (Tk)	966.66	5678.5
Labor (Tk)	1450	8517.8
Fertilizer (Tk)	2200	12923.6
Processing (Tk)	442.8	2601.3
Total variable cost (Tk)	**9476.2**	**55666.8**
Rice Production (Tk)	11716.6	68828.4
Straw yield (Tk)	500	2937.20
Gross return (Tk)	12216.6	71765.6
Net return	2753.8	16177.13
Benefit-cost ratio	1.32	-
Yield t/ha	5.9	-

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

The conclusions drawn from this study are summarized below.

1) Four factors, namely, time of harvest of Aman crops, soil moisture status at the time of harvest, access to capital and irrigation determine the farmers' decision regarding selection of non-rice crops. Some farmers do not cultivate Aman rice because they want to start early in the Rabi season and grow onion/garlic or HYV wheat. Basically, they are owners of high land and they believe that early Rabi crops are more profitable than Aman rice.

2) If the preceding Aman crop is harvested within November then the farmers with no access to capital and irrigation grow a mixed crop of mustard and lentil. On the other hand, farmers who have access to capital and irrigation grow a mixed crop of onion or garlic. If the Aman crop is harvested after November, then the farmers grow coriander seed, sesame or local wheat. But if they have access to capital and irrigation, then they grow HYV rice.

3) The actual water use by onion as practiced by the farmers was only about 56 mm which was almost one third of the potential requirement and only about 20% of the water requirement recommended by BARI. Farmers had 26% lower yield of onion compared to BARI but because of higher price, their BCR was almost 21% higher than that of BARI.

4) The actual water use by garlic as practiced by the farmers was 74 mm which was almost one fourth of the potential requirement and only about 28% of the water requirement recommended by BARI. The farmers had 81% lower yield of garlic compared to that of BARI and their BCR was almost 70% lower than that of BARI.

5) The actual water use by wheat as practiced by the farmers was about 108 mm which was about two-fifths of the potential requirement and only about 37% of the water

requirement recommended by BARI. The farmers had 53% lower yield of wheat compared to that of BARI and their BCR was almost 60% lower than that of BARI.

6) The farmers were unaware of BARI recommended practices on irrigation and inputs use and as such used little or no irrigation and unbalanced amounts of fertilizer.

7) The price of non-rice crops in the immediate past year strongly influenced the farmers' decision regarding the use of inputs. A lower price discouraged the use of more inputs and vice versa.

5.2 Recommendations

Based on the findings of the study, the following recommendations can be made.

- The DAE should take the necessary steps to make the farmers aware of the proper number, timing and amount of irrigation application and fertilizer use for non-rice crops.
- A pre-set price of non-rice crops would go a long way in stabilizing both the production and profit by the farmers from non-rice crops.
- This study was condncted in six farmers' fields and forty sample farmers in four villages of an Upazila. In order to validate the findings of this study, further studies are needed with larger sample in more non-rice growing Upazilas.

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