Yield and Water Requirement of Indigenous Potato Growm on a Clay Terrace Soil of Bangladesh

Chowdhury Hasneen, Mst. Mushfiqua
MS student, Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University

Sirajul Karim, A. J. M.

Mofazzal Hossain, M.
Bangabandhu Sheikh Mujibur Rahman Agricultural University

Egashira, Kazuhiko
Laboratory of Soil Science, Division of Soil Science and Plant Production, Department of Plant Resources, Faculty of Agriculture, Kyushu University

https://doi.org/10.5109/24412

出版情報：九州大学大学院農学研究院紀要. 45 (2), pp.621-629, 2001-02-28. Kyushu University

J. Fac. Agr., Kyushu Univ., **45** (2), 621–629 (2001)

Yield and Water Requirement of Indigenous Potato Grown on a Clay Terrace Soil of Bangladesh

Mst. Mushfiqua Hasneen Chowdhury*, A. J. M. Sirajul Karim, M. Mofazzal Hossain** and Kazuhiko Egashira*****

Laboratory of Soil Science, Division of Soil Science and Plant Production,
Department of Plant Resources, Faculty of Agriculture,
Kyushu University, Fukuoka 812–8581, Japan
(Received October 31, 2000 and accepted November 10, 2000)

A field experiment was conducted in the rabi (dry) season of 1997–98 on a clay terrace soil of Bangladesh, in order to study the effects of rice straw mulching and irrigation on the yield, total water use, and water use efficiency of an indigenous low–yielding variety of potato, "Lal pakhri". The experiment was executed in the split–plot design comprising the combination of the two mulching conditions as a main plot and five frequencies of irrigation distributed as a subplot. Irrigation is indispensable in the rabi season of Bangladesh and the yield was significantly lowest in the treatment of no irrigation after establishment of seedlings. Rice straw mulch was found to conserve soil moisture and to maintain a higher moisture regime in each irrigation level throughout the cropping period. The treatments of rice straw mulching and the single irrigation at 30 days after sowing were the best combination with a satisfactory high yield of 7.9 Mg ha^{-1} in the 1997–98 rabi season having a good amount and distribution of rainfall. The water requirement was 145.8 mm to give the highest water use efficiency of 54.5 kg ha^{-1} mm^{-1}.

INTRODUCTION

Potato is an important vegetable crop in Bangladesh. It is grown in 133,000 ha of land in the country (Bangladesh Bureau of Statistics, 1997). The potato varieties in Bangladesh may be divided into two categories: modern potato varieties (MPV) and indigenous potato varieties (IPV). In general, the varieties introduced since early sixties are known as modern varieties. The varieties known as indigenous varieties were introduced long before from different parts of the world and have lost their identity but are still under cultivation with different popular names. Although increase in the potato cultivation area in the country from 35,000 ha during late forties to 133,000 ha in the recent years is mainly due to the introduction of MPV, the cultivation area under IPV did not decline during the period. Rather there has been some increase in the area under IPV reaching to the present 46,000 ha. The reasons for growing IPV are the high market value, good market demand (Scott, 1988; Siddique, 1989; Siddique and Rashid, 1990), better storability under room condition, better taste of tuber, low input cost, and more

* MS student, Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur 1703, Bangladesh; currently serving at Bangladesh Agricultural Development Corporation, Bangladesh

** Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur 1703, Bangladesh

*** Corresponding author (E–mail: kegashi@agr.kyushu–u.ac.jp).

resistance to pest attack. The only drawback of IPV is the low yield.

The extensive deltaic floodplain soils of silty texture in Bangladesh are unique for potato production. Having a well-defined winter season, Bangladesh is climatologically suitable for producing potato to a significant extent. Potato is grown during the rabi (cool-dry winter) season (November to March) in the country when rainfall is limited and unpredictable (Karim and Egashira, 1994). Therefore, irrigation plays a vital role to meet its evapotranspiration demand for the maximum tuber yield.

Potato has a shallow rooting system and needs frequent irrigation allowing minimum depletion of soil water. The yield of potato is drastically reduced if water deficit arises in some particular growth stages. Khan *et al.* (1992) reported that stolonization and bulking are the two important growth stages sensitive to water stress. In addition, excess soil moisture often results in rotten tubers. So the risk of both under- and over-irrigation must be avoided. This necessitates to determine water requirement and irrigation frequency of potato and to conserve the residual soil moisture as much as possible to reduce the irrigation need of the crop.

The main way to conserve the soil moisture is to reduce its loss. Use of rice straw as surface mulch in potato cultivation is a common practice in some areas of Bangladesh. Straw mulching reduces evapotranspiration and conserves moisture in the soil profile, thereby reducing the irrigation need of crops (Jalota and Prihar, 1990; Rydberg, 1990). It has now become necessary to quantify the moisture conserving ability by straw mulching and subsequent reduction in irrigation water without hampering the maximum yield potential of indigenous potato in the specific agro-ecological regions of the country. The present investigation was undertaken to study the yield and water requirement of indigenous potato in relation to different irrigation frequencies under the mulched and unmulched conditions in Shallow Red-Brown Terrace Soil of Madhupur Tract in Bangladesh.

MATERIALS AND METHODS

Location and soil

The field work was conducted at the experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh, during November 1997 to February 1998. It is located at the center of Madhupur Tract (24° 05' N latitude and 90° 16' E longitude) at an elevation of 8.4 m above MSL and is 40 km north of Dhaka, the capital.

The farm soil is a terrace soil, belonging to Salna series, and has been classified as Shallow Red-Brown Terrace Soil according to the Bangladesh soil classification system (Brammer, 1971; Saheed, 1984) which is equivalent to Ochrepts in Soil Taxonomy. The soil is silty clay loam in texture. The bulk density was 1.10 g cm^{-3} at the surface (0–10 cm) and as high as 1.60 and 1.71 g cm^{-3} at 10–20 and 20–30 cm depths, respectively, indicating the impeded internal drainage condition of the soil. Chemical properties of the soil up to the depth of 20 cm were as follows: pH (H_2O), 6.2; organic C, 9.2 g kg^{-1}; total N, 0.8 g kg^{-1}; available P by the Olsen method, 13.5 mg kg^{-1}; and exchangeable K, 0.34 $cmol_c$ kg^{-1}.

Experimental design and treatments

The experiment was laid out in the split–plot design with three replications. The two mulching treatments were assigned to main plots and the five irrigation treatments were arranged as subplots. The size of each plot was 3.0 m×2.4 m having plot–to–plot and block–to–block spacings of 1.5 and 2.0 m, respectively. A shallow drain was made around each plot to remove rainwater. The mulching and irrigation treatments were arranged as follows.

Two mulching treatments were:

M_0 : no mulching;

M_1 : covering the soil surface by 12– to 15–cm thick rice straw (mulching).

Five levels of irrigation treatments were:

I_0 : no irrigation after seedling establishment;

I_1 : one irrigation at 30 days after sowing (DAS) of potato tubers;

I_2 : two irrigations at 30 and 45 DAS of potato tubers;

I_3 : three irrigations at 30, 45, and 60 DAS of potato tubers;

I_4 : four irrigations at 30, 45, 60, and 75 DAS of potato tubers.

Measured amounts of water were irrigated to bring the soil moisture to field capacity up to the rooting depth (Giriappa, 1988). This was done to avoid deep percolation loss of irrigated water.

Test crop

The indigenous low–yielding variety of "Lal pakhri" was used as the test crop. This was collected from Bogra district, the potato growing district in Bangladesh. The size of tuber varied between 3 and 5 cm in diameter. The pulp was reddish–brown and the flesh was little sticky and light–yellowish (creamy) in color.

Fertilizer application, sowing of tuber seeds, and cultural operations

Well–decomposed cowdung was applied at the rate of 15 Mg ha^{-1} during final land preparation. The crop was fertilized with 150 kg N, 60 kg P_2O_5, 150 kg K_2O, and 20 kg S per ha as urea, triple super phosphate, muriate of potash, and gypsum, respectively. Triple super phosphate and gypsum were applied during final land preparation. Half of urea and the whole muriate of potash were applied at 15 days after germination (DAG) of seedlings and the rest half of urea was at 45 DAG.

Healthy and uniform potato tuber seeds (2.5 to 3.0 cm in diameter) were sown in lines on November 23, 1997 at 4 to 6 cm below the soil surface. The row–to–row and seed–to–seed spacings were 60 and 20 cm, respectively. The seeds were covered immediately with the adjacent loose soils. There were 4 rows in a plot having 15 seeds in a row. After sowing of seeds, the soil was moistened uniformly every alternate day for three weeks by a calibrated watering can to ensure proper germination and establishment of seedlings. Soil loosening, weeding, and preparation of ridges along the plant rows were done at 22 to 25 DAS. The mulched plots were covered with 12– to 15–cm thick layer of rice straw. The crop was sprayed with Diathane M–45 at a regular interval of 15 days for protection against leaf blight disease.

Harvest of potato

Potato tubers were harvested on February 18, 1998 and cleaned by shaking and then rubbing with cloth. Twenty potato plants in the middle two rows of each plot were selected randomly to record the data on the number of tubers per plant, the size of tubers, and the yield. Three different sizes of tubers were categorized based on three diameter ranges of <35, 35–45, and >45 mm measured by slide calipers. Composite samples of each treatment of the three replicates were made to determine the tuber sizes. Hence, statistical analysis was not done on this parameter. The percentage in each size was computed on weight basis.

Soil moisture monitoring

Soil moisture was monitored gravimetrically at one out of three replicates for the respective treatments once a week at two different depths (0–10 and 10–20 cm) from sowing to harvest of potato. The data were used for computing irrigation requirement of the crop and soil water depletion.

Irrigation requirement (IR) was calculated as follows:

$$IR = \{(M_{FC}-M_{PI})/100\} \times A \times D$$

where M_{FC} is soil moisture at field capacity (% by weight), M_{PI} is soil moisture prior to irrigation (% by weight), A is bulk density of soil (g cm^{-3}), and D is the rooting depth (cm; maximum depth of 20 cm was considered as such).

Soil moisture depleted (S) was calculated as follows:

$$S = \{(M_S-M_H)/100\} \times A \times D$$

where M_S is soil moisture at sowing (% by weight), M_H is soil moisture at harvest (% by weight), and A and D are the same as those in the above equation.

Total water use and water use efficiency

Total water use (TWU) was determined using the water balance equation given by Rose (1966) by assuming the drainage component as zero. The TWU is the summation of measured quantities of irrigation water, seasonal rainfall, and profile water contribution. This is expressed as follows :

$$TWU = IR + ER + S$$

where IR is irrigation requirement (mm), ER is seasonal effective rainfall (mm), and S is soil water depleted (mm). Under the prescribed condition, TWU can be regarded to be nearly equal to evapotranspiration (ET). Water use efficiency (WUE) was calculated by dividing the yield by TWU.

Statistical analysis

Duncan's multiple range test was applied to the statistical analyses of the number of tubers per plant and the yield data of potato.

RESULTS AND DISCUSSION

Climate, rainfall, and soil moisture regime

The climate of the whole country of Bangladesh is dominated by the tropical and subtropical monsoons with most rainfall occurring between June and September. The mean annual rainfall of Madhupur Tract, located in the center of Bangladesh, is about 2200 mm which is higher than the annual potential ET (PET) of about 1700 mm, but the rainfall is so scarce in the rabi season that PET always exceeds rainfall, resulting in a severe water stress condition (Karim and Egashira, 1994).

The monthly mean maximum and minimum air temperatures at the experiment site in the 1997–98 rabi season, recorded at the BSMRAU meteorological station, were 22 to 30 and 13 to 19 °C, respectively, for the months of November through February. Temperature is favorable for growing of potato.

The total rainfall at the experiment site during the rabi season of 1997–98 was 55 mm, with the distribution of 23, 30, and 2 mm for the months of December, January, and February, respectively. The rainfall distribution in this particular season was good because it was well–distributed at the active vegetative growth period of potato and

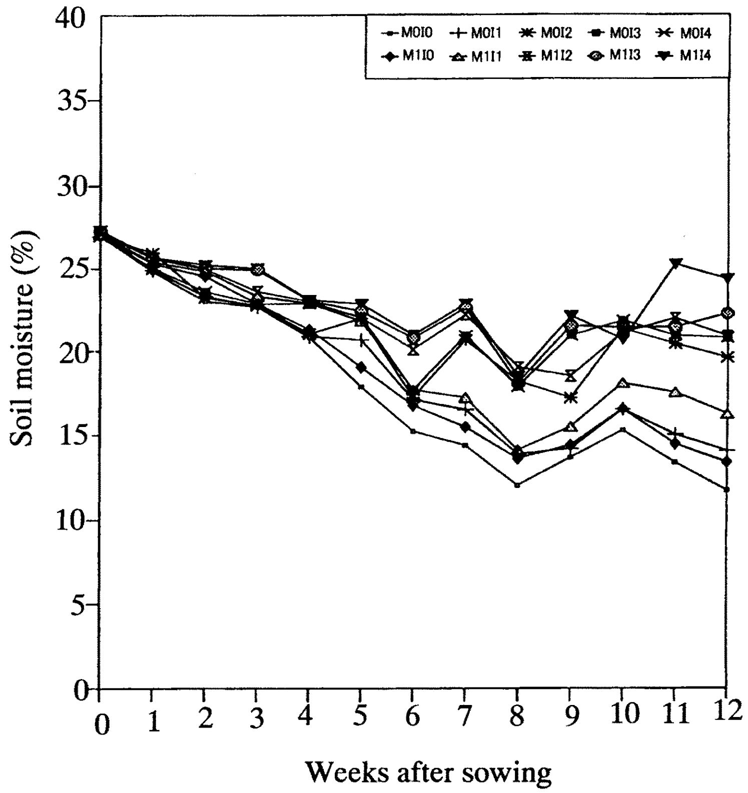

Fig 1. Soil moisture regime as affected by mulching and irrigation treatments.

became effective to substitute a remarkable amount of irrigation water.

Soil moisture regime (0–20 cm depth) under different treatments of irrigation and mulching throughout the cropping period is reproduced in Fig. 1. Initially, a common watering just after sowing has moistened the soil to 27% in moisture content, near the field capacity of 30.2%. Subsequent common watering up to three weeks after sowing has kept the soil moisture above 22% that has ensured proper germination and establishment of potato seedlings.

The mulched plots had always higher soil moisture in each irrigation treatment. The soil moisture in I_0 decreased continuously with time, came down below the wilting point of 15.6% for three weeks in the unmulched plot but for two weeks in the mulched plot during mid-cropping period. Occasionally, rainfall has interfered with the continuous downward trend of soil moisture. The soil moisture in M_0I_1 remained below the wilting point for two weeks from 8th week after sowing. In the mulched plot of the same irrigation treatment (M_1I_1) it remained only for one week below the wilting point. Soil moisture in I_2, I_3, and I_4 had never come below the wilting point irrespective of the mulching.

Number of tubers per plant and the tuber-size distribution

Data on the number of tubers per plant are shown in Table 1. The number of tubers was higher for the mulched plot than for the unmulched plot by 11%, although the

Table 1. Effects of mulching and irrigation on the number of tubers per plant, tuber-size distribution, and yield of an indigenous potato variety.

Treatment	Number of tubers per plant	Tuber-size distribution (% by weight)			Tuber yield (Mg ha^{-1})
		<35 mm	35–45 mm	>45 mm	
Mulching					
M_0	26.5				6.8
M_1	29.3				7.8
Irrigation					
I_0	20.6 c				5.1 b
I_1	28.1 b				7.2 a
I_2	29.1 ab				7.8 a
I_3	30.4 ab				8.1 a
I_4	31.4 a				8.4 a
Mulching × Irrigation					
M_0I_0	19.6 e	29.4	49.1	21.5	4.6 f
M_0I_1	26.2 cd	20.5	43.3	36.3	6.5 de
M_0I_2	27.3 bc	17.8	48.4	33.9	7.2 cd
M_0I_3	29.3 abc	19.6	50.5	29.9	7.6 bcd
M_0I_4	30.3 abc	20.9	50.4	31.7	7.9 abc
M_1I_0	21.7 de	21.9	45.0	33.1	5.5 ef
M_1I_1	30.0 abc	21.4	46.2	32.4	7.9 abc
M_1I_2	31.0 abc	14.1	52.1	33.8	8.3 abc
M_1I_3	31.6 ab	20.2	48.7	31.1	8.6 ab
M_1I_4	32.5 a	18.3	49.0	32.6	8.9 a

Treatments having a common letter in a column are not significantly different at 5% level.

statistical analysis was not done due to two factors. The main effect of irrigation on the number of tubers per plant was significant and positive. The interaction effect of mulching and irrigation on the number of tubers per plant was also significant. This information reveals that maintenance of higher soil moisture through irrigation and straw mulching favors increase in the number of tubers per plant. Higher values were always recorded in the mulched condition under each irrigation frequency, but the significant difference was not found between the mulching and no–mulching under the same irrigation level.

Data on the tuber–size distribution were taken, because the market value of potato varies to some extent with the tuber–size, being higher for the larger one. The size distribution of tubers according to three different sizes is presented in Table 1. There was no remarkable variation in tuber–sizes with the variation of irrigation frequency or the mulching treatment. In general, about half of the total weight of tubers belonged to the medium–sized category (35–45 mm diameter), being followed by the larger grade (> 45 mm) and the smaller one (< 35 mm). The present findings reveal that irrigation or mulching does not create any remarkable impact on the tuber–size. The compact clayey nature of the terrace soil may be responsible for this poor response, although a greater proportion of larger–sized tubers in properly irrigated potato plots was observed by Khan *et al.* (1990).

Tuber yield, total water use, and water use efficiency

Yield data are shown in Table 1. The difference in the tuber yield between the mulched and the unmulched plots could not be analyzed statistically due to the minimum number of treatments. The mulched plots gave an average yield of 7.8 Mg ha^{-1} against 6.8 Mg ha^{-1} in the unmulched plots, indicating that use of straw mulch lead to yield increase by 15% over the unmulched condition. The main effect of irrigation on the tuber yield was significant. Highest yield of 8.4 Mg ha^{-1} was recorded in I_4, but there was no significant difference in the tuber yield among I_4 through I_1. The minimum yield of 5.1 Mg ha^{-1} was found under the no–irrigation condition, revealing that irrigation is unavoidable to get the higher yield of potato.

The interaction effect of mulching and irrigation on the tuber yield was significant. The highest yield of 8.9 Mg ha^{-1} was recorded in M_1I_4 which was followed by M_1I_3, M_1I_2, M_1I_1, and M_0I_4 and there was no significant yield difference among them. The mulched plot had always given insignificantly higher yield than the unmulched one under the same irrigation level, except for I_1 level.

Among the treatments giving the statistically highest range of the tuber yield, the lowest TWU of 145.8 mm was exhibited by M_1I_1 that has led to achievement of the highest WUE of 54.5 kg ha^{-1} mm^{-1} (Table 2). The irrigation water required under this treatment was 62.6 mm which was lower by 70.9 mm than that recorded under M_1I_4 giving the highest yield. Uniform distribution of rainfall during the cropping season and minimizing the water loss by application of rice straw mulch might have fulfilled major amounts of water requirement by the crop under the single irrigation at 30 DAS. Under the same irrigation level, mulching saved 2 to 14 mm of irrigation water.

From the standpoint of WUE, the treatment of M_1I_1 could be considered as the best combination of mulching and irrigation treatments with the acceptable tuber yield of

Table 2. Effects of mulching and irrigation on the parameters relating to water use of an indigenous potato variety.

Treatment	Soil water depleted (mm)	Irrigation water (mm)	Total water use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})
M_0I_0	40.6	48.0	142.8	32.4
M_0I_1	34.4	64.5	153.1	42.5
M_0I_2	19.8	95.8	169.8	42.4
M_0I_3	16.6	119.8	190.6	39.7
M_0I_4	7.8	147.1	209.1	37.6
M_1I_0	36.3	48.0	138.5	39.7
M_1I_1	29.0	62.6	145.8	54.5
M_1I_2	16.9	86.2	157.3	52.4
M_1I_3	13.5	108.9	176.6	48.8
M_1I_4	7.3	133.5	195.0	45.7

Initial common watering (48.0 mm) which is included in irrigation water and seasonal effective rainfall (54.2 mm) were considered for computing TWU.

7.9 Mg ha^{-1}. Under favorable rainfall amount and distribution, rice straw mulching may become effective in the terrace soil in saving a considerable amount of irrigation water and maintain higher soil moisture regime under single irrigation at 30 DAS to give a satisfactory higher yield of potato. Rasul *et al.* (1989) found the best performance of an indigenous variety of potato in a soil of Debigonj area in Bangladesh by providing single irrigation at 30 DAS, similar to our findings. Although the treatment of M_1I_4 gave the highest yield, the high irrigation water by 70.9 mm compared to the M_1I_1 treatment was supplied to produce only 1.0 Mg ha^{-1} more tuber. The poor farmers of Bangladesh prefer the minimum use of input to get the best return through good management practices. Under this circumstances it is recommended to use minimum irrigation water and to adopt the best soil management practice to protect its loss either by evaporation or by percolation.

CONCLUSIONS

Irrigation is indispensable for growing an indigenous potato variety, 'Lal pakhri' in Shallow Red-Brown Terrace Soil of Bangladesh. The water requirement of an indigenous potato was 146 mm in the rabi season of 1997–98, supplied through rainfall, soil moisture, and single irrigation at 30 DAS. Under this condition, the highest WUE of 54.5 kg ha^{-1} mm^{-1} was recorded with the tuber yield of 7.9 Mg ha^{-1}. Insignificant difference of the tuber yield was found between the mulched and unmulched conditions, but use of 12- to 15-cm rice straw mulch was beneficial for conserving soil moisture to save irrigation water.

REFERENCES

Bangladesh Bureau of Statistics 1997 *Yearbook of Agricultural Statistics 1992*. Ministry of Planning, Government of Bangladesh, Dhaka, Bangladesh, p. 103.

Brammer, H. 1971 *Soil Resources*. Soil Survey Project Bangladesh. AGL. Sf/Pak. 6. Technical Report

No. 3. FAO–UNDP, Rome, Italy

Giriappa, S. 1988 *Water Use Efficiency in Agriculture*. Oxford and IBH Publishing Co., Delhi, India, pp. 6–7

Jalota, S. K. and S. S. Prihar 1990 Effect of straw mulch on evaporation reduction in relation to rates of mulching and evaporavity. *J. Ind. Soc. Soil Sci.*, **38**: 204

Karim, A. J. M. S. and K. Egashira 1994 Agroclimatic conditions and soil water balance in the terrace soil area of Bangladesh. *Bull. Inst. Trop. Agric., Kyushu Univ.*, **17**: 45–58

Khan, M. S., M. Rahman, S. A. Mallik, R. A. Begum, U. K. Saha, and H. Kabir 1990 Yield response of potato to water at different growth stages. *Bangladesh J. Agric.*, **15**: 189–194

Khan, M. S., M. S. Islam, U. K. Saha, and H. Kabir 1992 Effect of irrigation and water relations of some exotic and indigenous potato varieties. *J. Ind. Potato Assoc.*, **19**:1–4

Rasul, M. G., A. I. Khan, H. H. Rashid, and M. M. Rashid 1989 Response of different potato varieties to different levels of irrigation. *Bangladesh Hort.*, **17**: 15–18

Rose, W. 1966 *Agricultural Physics*. Pergamon Press, New York, p. 226

Rydberg, T. 1990 Effect of ploughless tillage and straw incorporation on evaporation. *Soil Till. Res.*, **17**: 303–314

Saheed, S. M. 1984 *Soils of Bangladesh: General Soil Types*. Soil Resources Development Institute, Dhaka, Bangladesh

Scott, G. J. 1988 *Marketing Bangladesh Potatoes; Present Patterns and Future Prospect*. CIP–ADAB, Bangladesh Agricultural Research Council, Dhaka, Bangladesh, p. 107

Siddique, M. A. 1989 *A Report on the Improvement of Indigenous Potato Varieties of Bangladesh*. Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh, p. 20

Siddique, M. A. and M. M. Rashid 1990 Scope for increasing the yield of indigenous potato varieties of Bangladesh. *In* "Proceedings of the International Seminar on Seed Potato", Bangladesh–Netherlands Seed Multiplication Project, Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh, pp. 160–171