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Effective and safe surface water management for reclamation and crop production in black alkali soil

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Abstract

A field experiment was planned and designed for in-situ water harvesting of surface water in black alkali soil during the year 1994 with the objectives of surface water harvesting, recycling, reclamation and crop production. The experiment was carried out for three years (1994-96) under rainfed condition with only in-situ water retaining technique by adopting raised and sunken bed system. After considering all the inflow and outflow parameters, crop requirement and crop adoption, a design of raised and sunken bed in ratio of 1:1 with vertical difference of 40 cm was considered appropriate on the basis of technical inputs. The crop selected on the basis of local climate was cotton (on raised beds) and paddy (in sunken beds). Apart from water harvesting and its recycling the in-situ retaining of water was necessary for effective and rapid reclamation of such soils. The initial three years result indicated that although the design was appropriate to retain rain water in the field but however it has some practical difficulty like at-least two events of heavy storms in all the three years caused runoff from the field and one or two long dry spell causing reduction in crop yield. These two events forced to an alternate ex-situ arrangement of a small water harvesting tank for storing some runoff water during heavy events and also sufficient for one irrigation to the crop during stress. The runoff of the field was collected in storage tank and was recycled during either stress or at recession of monsoon. The supply of one or two irrigation to the crop led two to three fold increase in yield during latter periods (1997-1998) of experiments and it also helped in increasing crop duration of paddy (from 90 to 110 days) and cotton (from130 to 150 days). The storage of water in sunken bed also helped in reducing the soil ESP to a great extent and shifting of soil from sunken bed to raised bed facilitated mixing of gypsum to a grater depth (0 to 40 cm) in raised beds. It can be concluded from five years of experiment that surface water can be utilized effectively for reclamation as well as crop production during Kharif season if raised and sunken bed system supplemented with a small storage tank is adopted. The ratio of raised and sunken bed and size of tank may be adjusted for other locality looking to the runoff potential of soil and rainfall of the area.

INTRODUCTION

The black alkali soils are normally found in tropical or semi-tropical climatic conditions where evaporation is always greater than precipitation. In such areas water remains a scarce commodity and its judicial use is mandatory for any purpose. The reclamation procedure requires ample of water for chemical reaction as well as for leaching of salts. In absence of irrigation water in such soils reclamation becomes a tedious job. Further, `these black alkali soils are generally characterized by poor hydraulic conductivity, high bulk density, highly dispersible and have low potentials (Gupta and Verma,1983). The survival of crop in such soils are normally not feasible either due to water stress or temporary water logging, crop growth suffers heavily on both the accounts. The reclamation with the help of chemical amendments need ample of water for efficient chemical reactions and leaching process. These soils are normally found in low rainfall areas heaving poor irrigation facilities. After adopting all the recommended management practices and necessary techniques, the effective depth of reclamation remains a limiting factor. Under such abnormal situations no farmer can think about rehabilitation of such typical black alkali soils for crop production. But, it is well-established proverb that every cloud has a silver lining and some time a curse becomes boon for the other reasons, the only thing is to search this breakthrough. Several workers have reported that these soils have almost negligible infiltration when soil ESP approaches to >35 (Gupta and Verma, 1985) due to dispersion of fine soil particles and clogging of micro-pores. Thus the soil can work, as impervious sheet and may prove good for storing of surface runoff during rains. Insitu and exsitu rainwater harvesting technique can provide sufficient tool for reclamation of such soils and a proper way for management of our natural resource. The water retained insitu will provide sufficient and justified amount of water for crop use and reclamation without damaging, while exsitu stored water is to be used only under stress conditions to optimize crop production. To provide adequate drainage for sensitive crops under normal conditions Gupta et, al, (1978) proposed raised and sunken bed system for normal black clay soil.

TECHNIQUES

Design of Land configuration

For insitue water conservation, on the basis of annual rainfall, runoff potential, rainfall intensity, rains probability and water losses (Table,1) it was decide to adopt some land configuration system that can provide sufficient insitu conservation for crop as well as for reclamation. It was considered that raised and sunken bed system is appropriate and but its design is to be specified.

Water conservation= Inflow- Outflow

Table 1. Average Monthly rainfall, PET (mm) and dry spell (days) in the monsoon season at Barwaha (Source: Ranade and Gupta,1991).

Months	Average Monthly Rainfall			Average potential evaporation (mm)	Continuos Dry spell	
	Most Drier	Middle Rainfall	Wet		50% probability	20% probability
June	46.8	83.6	104.9	224.1	-	-
July	164.0	176.3	268.8	133.8	9.9	13.9
August	175.3	277.7	234.9	119.0	9.1	12.0
September	47.8	60.7	227.0	123.0	12.3	18.0
Seasonal	-	-	-	-	17.0	24.3

Looking to the spatial weather conditions and physico-chemical nature of the soil it was considered that Water available in sunken beds= Rain water + Flow from raised bed- Out flow from sunken beds

$AW = R + (R \times r \times t) – (s \times d + E)$

Where, AW= water available for crop (mm) in sunken beds, R = Rains available (mm) in crop season, r = Runoff coefficient of soil, t = Ratio of raised bed to sunken bed,s = Seepage loss (mm) per day, d = Number of days (water storage),E= Open pan evaporation (mm) during crop season.

The other inflow and out flow parameters were considered as negligible after considering all soil water parameters and weather conditions. The annual rain fall of the experimental area is 750mm, with maximum rainfall (235mm) of August month, dry spell of 14-15 days (Table-1), crop requirement (Michel, 1978) of 450mm at raised bed (Cotton) and 1000-1200mm in sunken beds (for Paddy), seepage loss of 5.0mm per day, runoff coefficient of 0.70 and considering other parameters as negligible it seems that land configuration of 1:1 raised and sunken bed is suitable.

For present experiment,

$$
\begin{aligned}
AW &= 750 + (750 \times 0.7 \times 1) - (0.5 \times 90 + 120) \\
&= 750 + 525 - (45 + 120) \\
&= 1275 - 165 \\
&= 1110 \text{ mm}
\end{aligned}
$$

After considering maximum rains of a month and rain interval it was computed that a difference of 40cm would work comfortably.

Design of water storage tank

The three years data (1994-1997) indicated that on a average about 200mm water is running out of field during strong storms. After considering unusual runoff from the field during strong storms and irrigation requirement during dry spells it was calculated that a tank design with gross size of 35x30m with net storage of 25x20x3m would serve the purpose for one-hectare area. This requires only 10 per cent of cultivated area.

EXPERIMENTALS

A field experiment was formulated and designed in such a fashion so as to achieve an efficient reclamation up to sufficient depth and to conserve rainwater for satisfactory crop production in black alkali soil under rainfed conditions. The experiment was conducted at Barwaha (76^0 01’ E and 22^0 14 ' N) district Khargaon, Madhya Pradesh for five successive years (1994 to 1998) in *Kharif* season. The annual precipitation of the area is about 730 mm. The chemical amendment (gypsum) was added to the soil (ECe- 3.5 dSm^{-1}, pH-8.6, ESP-65 and CEC 40 cmol (p^+) kg^{-1}) @ 80% of laboratory estimated gypsum requirement in plough layer (0-15cm). Raised and sunken beds of various widths (i.e. 7.5, 6.0 and 4.5 m) were prepared in 1:1 ratio after considering the entire inflow and out flow parameters and crop water requirement. The soil was shifted with the help of tractor and manual laboures in such a way that a difference of 40-cm vertical interval was achieved between raised and sunken bad. To minimize soil loss from raised bed a vegetative cover of native grasses (5% of width in each side) were allowed to grow and maintained throughout the season. The exposed soil of sunken bed was treated with gypsum before the start of the experiment. Cotton (var. 79-BH-5-3) was planted on raised beds and paddy (var. IR-36) in sunken beds and all the recommended agronomic practices were followed. The water stored after first rains which carries high amount of soluble salts was safely disposed off from the field (sunken bed) to avoid any salt injury to the crop. Paddy yields for the first three years (1994 to 1996) suggested that the design of only insitu water conservation had some limitation for getting optimum paddy yield. The crop suffered in early as well as latter stages due to long dry spells and the crop was forced to mature in 90 days periods. This design was therefore, supplemented with a small water- harvesting tank (sufficient for one irrigation) and the stored water were re-cycled during stress period.

RESULTS

Soil Reclamation

The five years results clearly indicate a sharp reduction in soil alkalinity. The soil alkalinity reduced to more than about 60% (soil ESP < 25) and upto a depth of 40 cm. The reduction in soil alkalinity was comparatively higher in sunken beds as compared to raised beds probably due to continuos submergence (>60 days) in sunken beds which favor better chemical reaction. The safe disposal of stored water after first rain reduced the damage of crop due to dissolution of salts and their accumulation at surface during summer. Monitoring the soil content of stored water throughout Kharif season also conferred this. The electrical conductivity of stored water after first rain was about 1.45 to 1.3 dSm^{-1} in two years respectively whereas after disposal it lowered down to level about 0.9 dSm^{-1}.

Soil Water Balance

Soil water balance was computed for estimation of crop water use with the help of inflow and outflow parameters. The main inflow sources were precipitation and profile moisture before the commencement of rains. The other inflow parameters like inflow seepage and upward flux was almost negligible due to very poor hydraulic conductivity. The main outflow sources were safe disposal of excess rainwater, change in soil moisture storage and downward seepage. The difference in inflow and outflow was considered as water available for plant growth. The measurement were carried out only for one bed of 15m width having 7.5m raised and 7.5m sunken bed considering that only a little change in data under various widths of raised and sunken bed as ratio was constant. The root zone depth was considered 50m for all-purpose. The five years data showed a strong variation due to very erratic rainfall events and long dry spells during first three years (1994-96). The first year (1994) witnessed a very wet season (1040 mm rainfall) where as second year (1995) was relatively dry and total rainfall was lower (618 mm) than normal rainfall (730 mm) of the area and third year (1996) it was again normal (923.1 mm).

The effective rain water conserved were only 731,633.9 and 723.1 mm in 1994,95 and 96 respectively and 390,70and 200 mm was disposed off either for safety measures or due to lack of storage capacity under strong storms. The conserved water was just sufficient for raising paddy crop but it failed to provide sufficient moisture to the cotton crop on raised bed particularly in latter stage as crop start showing stress. The effective conservation of rainwater in terms of percentage it was 70.0, 62.2 and 78.5 per cent during the year

1994,1995 and 1996 respectively. The paddy yield during corresponding years were 4112, 2558 and 1684 kg ha^{-1} and cotton yield was 419, 490 and 435 kg ha^{-1} (Table, 3). The critical examination of crop yield indicates that paddy yield is highly influenced by the rainfall, dry spells and onset and withdrawal of mansoon season although effective conservation of water was of high degree. The cotton yield was almost constant in all the years being planted on raised bed having proper and adequate drainage. Looking to the risk of paddy crop in sunken beds the experiment was redesigned and supplemented with the construction of a water-harvesting tank to store excess rainwater during the month of July and August. The stored water was used to irrigate the sunken bed either after the transplantation (2nd week of July) for timely transplanting or after the withdrawal of mansoon to avoid forced maturity to the crop. Thus, life span of paddy crop increased from 90 days to 110 days due supply of irrigation. One irrigation of 100 mm was also supplemented during the dry spell of August/September as experienced. The result showed that the effective conservation of rainwater on the field was 64.8 and 70.2% during the year 1997 and 1998. Whereas remaining water was stored in storage tank and thus the total effective utilization reached up to 80 to 85 % during the corresponding the years paddy yield reached up to 4918 and 5612 kg ha^{-1} and cotton yield was 571 and 610 kg ha^{-1}. The five years (1994 to 1998) experimental results therefore, suggested that water storage tank along with raised and sunken bed system ensures good paddy yield. The reclamation procedure was more effective in sunken bed as compared to raised bed due to continuous standing of water during rainy season.

Table 2. Water balance under raised and sunken bed system and crop availability (mm) (Computed only for 7.5m width system).

Factors	1994	1995	1996	1997	1998
A. Inflow parameters:					
(i) Rainfall during crop	1040.0	613.6	923.1	639.0	882.3
(ii) Soil water before sowing	82.9	90.3	86.6	84.4	89.2
Total	1122.9	703.9	1011.7	824.4	871.5
B. Outflow parameters:					
(i) Surface runoff	309.0	70.0	200.0	225.0	225.0
(ii) Change in soil storage	200.0	192.0	196.0	198.0	220.5
Total	509.0	262.0	396.0	423.0	445.5
Water available for crop (A-B)	613.9	441.9	615.7	401.0	746.0
Water use by crop					
a. Cotton (July to October)	210.0	156.0	190.7	165.0	197.2
b. Paddy	1017.8	727.8	1040.7	637.0	1294.5
Total Available water					
a. Cotton	410.0	318.0	386.7	363.0	397.7
b. Paddy	1227.8	919.8	1236.7	835.0	1495.0

Crop Yield

Paddy: The paddy grain yields for five consecutive years recorded from sunken beds (Table 3) revealed that the grain yield was comparatively higher during 1998 as compared to all the other years due to higher amount of available water either from insitu or exsitu storage. The mean paddy yield was 3885, 2511, 1524, 4760 and 5551 kg ha^{-1} during the five years 1994, 1995, 1996, 1997 and 1998 respectively. The number of irrigation supplied through storage tank during stress were one in 1997 and two in the year of 1998.In all the years maximum paddy yield (3950, 2558, 1684, 4708 and 5612 kg ha$^{-1)}$ were obtained in sunken beds of 7.5m width and was followed by 6m bed width. The bed width of 4.5m had the minimum yield in all the years as compared to others. It is therefore, evident from the study that paddy can survive in black alkali soils even under low rainfall but moisture stress in some parts of crop physiological period may result in low crop yield. The system becomes very vital if there is provision to supplement the crop with recycling of rainwater stored outside the field in storage tank during the stress or after cessation of monsoon for optimizing the crop yields.

Table 3. Paddy and seed cotton yields (kg/ha) from raised and sunken bed systems under different beds width in 1:1 ration for five years.

Width of beds (mm)	Paddy					Cotton				
	94	95	96	97	98	94	95	96	97	98
4.5	3897	2493	1429	4663	5520	240	430	250	365	465
6.0	3990	2483	1460	4918	5520	360	463	329	571	610
7.5	4112	2558	1684	4708	5612	419	490	435	508	600

Cotton: The highest seed cotton yield (Table 3) was recorded on raised beds having width of 6.0m and was followed by 7.5m in all the years and the lowest was with 4.5m bed width. The crop was provided one irrigation during the year 1998 during a long dry spell. The crop yield was in general not affected by the amount of rainfall but mostly by distribution pattern that is why the cotton yield was more during 1995 as compared to 1994 and 1996. The assured irrigation during last two years was the reason for higher cotton yield.

CONCLUSIONS

The five years (1994 to 1998) experiments on surface rain water management's result concludes that raised and sunken bed land configuration along with a small water storage tank can surve the purpose of reclamation and satisfactory crop production in black alkali soils in the areas having modest rainfall. The raised and sunken bed system helps in increasing effective depth of reclamation. Although the design was very much effective for present conditions but the ratio of raised to sunken bed and size of water harvesting tank may change depending on the rainfall, alkalinity of soil and weather conditions.

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