Performance Evaluation of Subsurface Drainage System in Mallapur Village of TBP Command Area

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The introduction of irrigated agriculture in the arid and semi-arid regions of India has resulted in the development of twin problems of waterlogging and salinity. The problems also occurred in the valley bottoms of the Tungabhadra Irrigation Project (TBP). The subsurface drainage system was installed at 40, 50 and 60 m drain spacing to reclaim the salt affected soils in an area of 50 ha in the farmers’ fields at Mallapur village, Sidhanur taluk, Karnataka. The monitoring and evaluation of subsurface drainage system revealed that, soil reactions (pH), soil salinity (ECₑ) of the soil were decreased and it has been observed that 40 m drain spacing found better in improving the soil properties and then followed by 50 and 60 m drain spacing. The monthly average drain discharge was found to be maximum in 40 m spacing followed by 50 and 60 m drain spacing during kharif 2014 and rabi 2014-15 seasons, thus drain discharge was inversely proportional to the spacing. The total quantum of salt disposed along the drain discharge during kharif 2014 and rabi-2014-15 was maximum in 40 m spacing (35.92 t ha⁻¹), followed by 50 m (23.53 t ha⁻¹) and 60 m (17.23 t ha⁻¹) drain spacing respectively. The total quantity of nitrogen loss (NO₃-N) during kharif 2014 and rabi 2014-15 was maximum in 40 m spacing (43.09 kg ha⁻¹), followed by 50 m (32.88 kg ha⁻¹) and 60 m (26 kg ha⁻¹) drain spacing respectively. Crop yield was increased to the extent of 60.2, 50.4 and 40.8 per cent in 40, 50 and 60 m drain spacing respectively and cropping intensity was increased from 147 to 171 per cent after the installation of drainage system.

Introduction

Food, fiber and fodder are the three most important agricultural products necessary for sustenance, the two important product basis, land and water are however, limited and degradable over year of continuous irrigation to grow the crops without natural drainage will lead to problem of waterlogging and salinity in irrigated and unirrigated agricultural lands. According to the Food and Agricultural Organization much of the worlds
land is not cultivated, but a significant proportion of cultivated land is salt-affected. Out of the current 230 M ha of world’s irrigated land, 45 M ha are waterlogged and salt-affected (19.5 per cent) and of the 1500 M ha under dry land agriculture, 32 M ha are salt-affected. These problems result in a monetary loss of about Rs. 1766.6 billion per annum and also about 1.85 M ha is being threatened by these problems every year. It is estimated that up to 20 per cent of irrigated land in the world is affected by different levels of salinity and sodium content (Fard et al., 2007). In India as a result of introduction of irrigation in agriculture has resulted in the development of the twin problem of waterlogging and soil salinization. Considerable areas have already gone out of production or are being experiencing reduced yields. The state of Karnataka in India is no exception to these phenomena as the command areas of its many irrigation projects are suffering from water logging and salinity problems. Tungabhadra Irrigation Project (TBP) command is one such area afflicted by these problems. Approximately, 3.5 lakh ha area has been affected by waterlogging and salinity problems in the state, of which about 80,000 ha is in the Tungabhadra Project accounting nearly 25 per cent of the command area of 3.63 lakh ha (Manjunatha et al., 2004).

The Rashtriya Krishi Vikas Yojana (RKVY) project was taken up with the main objective of increasing agricultural production and for sustainable irrigated agriculture in the command area and to demonstrate the drainage and water management technology towards tackling the twin problems of waterlogging and soil salinity. Under the above project, about 50 ha area was selected in the Mallapur area of Sindhur taluk, Raichur district for project activities. Based on detailed pre-drainage investigations, the appropriate subsurface drainage system were designed and executed during 2012-13 and was monitored for two seasons viz., kharif 2014 and rabi 2014-15.

Materials and Methods

Study site

An area of 50 ha was selected at Mallapur village, Sindhur taluk, Raichur district at which the subsurface drainage system was installed for the reclamation of waterlogged and salt affected areas in the farmers field. The study area lies under 15° 46 'N latitude and 76° 46 ' E longitude at an elevation of 377 m from mean sea level. The area is a part of semi-arid region characterized by mild winter short monsoon and hot summer. The mean annual temperature is above 22º C. Summer season is very hot with a temperature of 43º C, whereas winter season (November to February) is relatively cool and dry. The hottest months are April and May, and December is the coldest month. The annual average rainfall nearest rain gauge station at Sindhur is 582 mm of which 448.14 mm occurs during south-west monsoon (June-September) which is about 77 per cent of the average annual rainfall. Paddy is the main crop in the study area and is being taken two crops annually.

A field experiment was carried out at farmers field in Mallapur village (Sindhur Taluk) in an area of 50 ha by considering three SSD spacing i.e., 40, 50 and 60 m each with a lateral depth of 1.0 m. The study was carried out during kharif 2014 (i.e. from September to December) and continued up to rabi 2014-15 (i.e. from January to May).

Observations recorded

The soil samples were collected before transplanting of kharif 2014 crop and after harvesting of kharif 2014 and rabi 2014-15 crop at different depth (0-15, 15-30, and 30-60
cm). The pH was determined by digital pH meter, the EC of soil samples were determined by digital EC meter (Jackson, 1973). The drain discharges were monitored weekly during kharif 2014 (August 2014 to December) 2014 and in summer (January to April) season of 2015. The leachate water samples were collected on weekly interval during the study period from the outlets of 40, 50 and 60 m drain spacing respectively and analyzed for water quality parameters like EC, salt disposed and nitrogen loss (Mejia and Madramootoo, 1998). The monthly average data of drain discharge, leachate water salinity, quantum of salt removed, quantity of nitrogen loss were calculated by using weekly data of respective parameters.

Cropping intensity was calculated by considering the cultivated area and total area (50 ha). The crop cutting was carried out in an area of 2 x 2 m² at selected locations distributed among all the drain spacing throughout the study area. The yield of crop was later converted to quintals per hectare.

Results and Discussion

Drain discharge

The monthly average drain discharge of kharif 2014 was presented in Table 1. From the results it observed that the maximum flow rate was noticed during October (2.67 mm d⁻¹) in all the spacing because of occurrence of heavy rainfall. The minimum flow rate was observed during December-2014 (1.36 mm d⁻¹) in all spacing. This was due to the fact that crop was matured and ready to harvest hence no irrigation was given.

The monthly average drain discharge of rabi 2014-15 was presented in Table 2. From the results it was observed that the maximum flow rate was noticed during March-2015 (2.22 mm d⁻¹) in all spacing because of occurrence of heavy rainfall along with the irrigation given to the field, while the minimum flow rate was observed during April-2015 (0.97 mm d⁻¹) in all spacing which was mainly due to crop was matured and ready to harvest hence no irrigation was given.

Salinity of leachate water

It was observed that during kharif 2014 (Table 3) the monthly average leachate salinity was found to be 9.97, 8.60 and 7.22 dS m⁻¹ in 40, 50 and 60 m drain spacing respectively. The maximum leachate salinity was observed in the month of September and lowest observed was in the month of December in all spacing.

Similarly, during rabi 2014-15 (Table 4) the monthly average leachate salinity was 9.93, 8.33 and 7.21 dS m⁻¹ in 40, 50 and 60 m drain spacing respectively. The maximum leachate salinity was observed in the month of January and lowest observed was in the month of April in all spacing.

A portion of the salts accumulated during summer (before kharif 2014) due to high evaporative demands and capillary action, were leached to lower layers and in turn to drain outlets during kharif 2014 and further during rabi 2014-15. This is mainly because of leachate water salinity decreased with time as a consequence of leaching that resulted in lower salinity.

Soil salinity

From the results it is observed that the maximum decrease in ECₑ from pre-drainage to post drainage was found in 40 m spacing i.e. 34.9 to 17.8 dS m⁻¹, 26.8 to 19.4 dS m⁻¹ and 24.6 to 21.1 dS m⁻¹ at 0-15, 15-30 and 30-60 cm depths respectively, followed by 50 m viz., 10.5 to 6.2 dS m⁻¹, 9.8 to 7.4 dS m⁻¹ and 9.2 to 8.1 dS m⁻¹ and 9.0 to 5.4, 8.4 to 6.3 and 7.3 to 6.7 dS m⁻¹ for 60 m drain spacing for
respective depths 0-15, 15-30 and 30-60 cm. It was observed that total percentage reduction in soil salinity as compared to the pre-drainage condition was maximum in 40 m followed by 50 and 60 m drain spacing. The ECe values were found to be directly proportional to the drain spacing as the leaching is inversely proportional to the spacing. Similar results are reported by Srikanth (2001) and Singh et al., (2002)

Impact of SSD on salt disposed

During the period of kharif 2014 (Fig. 1), the total quantum of salt disposed was maximum in 40 m spacing (20.33 t ha⁻¹), followed by 50 m (13.42 t ha⁻¹) and 60 m (9.62 t ha⁻¹) drain spacing respectively. The maximum salt disposed was noticed during October-2014 in all spacing, while the minimum salt disposed was observed during December-2014 in all spacing. Similarly, During rabi 2014-15 (Fig. 2), the total quantum of salt disposed was maximum in 40 m spacing (15.59 t ha⁻¹), followed by 50 m (11.11 t ha⁻¹) and minimum (7.61 t ha⁻¹) was observed in 60 m drain spacing respectively.

The maximum quantity of salt disposed was noticed during March-2014 in all spacing, while the minimum quantity of salt disposed was observed in the month of April-2014 in all spacing.

It is observed that in the month of October in kharif 2014 and March-2014-15 in rabi 2014-15 season irrigation along with rainfall leads to maximum flow rate of drain discharge and in turn drain discharge will carry more amounts of salts along with it. In the month of December during kharif 2014 and April in rabi 2014-15 seasons field was left for drying, to carry out the easy harvesting operation hence drain discharge was very less resulted in to carry less amount of salts during these months.

Impact of SSD on nitrogen loss

The monthly nitrogen loss along with the drain discharge during kharif 2014 is presented in Figure 3. A higher nitrogen loss was observed during September month as the fertilizer (urea) applied during that was maximum in which 50 per cent of recommended dose of fertilizer was applied during first week and 25 per cent during last week of September of kharif 2014. During rabi 2014-15 (Fig. 4) 50 percent of nitrogen was applied during January month and another 50 percent applied during February month but nitrogen loss observed to be maximum during February month because of the fact that drain discharge was high in February month as compared to the January month. It is also observed that higher nitrogen loss was noticed in 40 m drain spacing followed by 50 and 60 m during all the months of both seasons. It is evident that closer drain spacing results into higher nutrient loss in the form of nitrate-nitrogen which adds up to the cost of cultivation. The wider drain spacing will help to conserve the applied fertilizer but may result in to ground water pollution.

Crop yield

Crop performance under subsurface drainage system was studied by crop cutting at 18 observation points distributed among the all spacing. During pre-drainage paddy yield was ranged from 22-27 q ha⁻¹. After installation of subsurface drainage, paddy yield was increased substantially from 22-27 q ha⁻¹ to 53.3, 48.8 and 44.5 q ha⁻¹ in 40, 50 and 60 m drain spacing respectively during kharif 2014 and improved further to 57.5, 52.2 and 46.7 q ha⁻¹ during rabi 2014-15 for the respective drain spacing. The per cent increase in paddy yield after harvest of kharif 2014 crop during 2014 and rabi during 2014-15 was calculated by taking the pre-drainage yield as reference and are presented in Table 3. After the harvest
of *kharif* 2014 crop, percentage increases in the yield were found to be 58.7, 48.8 and 39.3 per cent in 40, 50 m and 60 m spacing respectively. Similarly after the harvest of *rabi* 2014-15 crop, further per cent increases in yield were 61.7, 52.1 and 42.2 per cent respectively for the spacing of 40, 50 m and 60 m spacing.

Table 1 Monthly average drain discharge during *kharif* 2014

| Spacing | Drain discharge, mm d\(^{-1}\) |
|---------|--------------------------------|
|         | Sep-2014  | Oct-2014  | Nov-2014 | Dec-2014 |
| 40 m    | 2.23      | 3.40      | 2.82     | 1.73     |
| 50 m    | 1.78      | 2.49      | 2.31     | 1.35     |
| 60 m    | 1.58      | 2.14      | 2.00     | 1.02     |
| Average | 1.87      | 2.67      | 2.38     | 1.36     |

Table 2 Monthly average drain discharge during *rabi* 2014-15

| Spacing | Drain discharge, mm d\(^{-1}\) |
|---------|--------------------------------|
|         | Jan-2015  | Fab-2015  | Mar-2015 | Apr-2015 |
| 40 m    | 1.82      | 2.43      | 2.68     | 1.16     |
| 50 m    | 1.45      | 2.12      | 2.23     | 0.94     |
| 60 m    | 1.30      | 1.60      | 1.74     | 0.81     |
| Average | 1.52      | 2.05      | 2.22     | 0.97     |

Table 3 Monthly average leachate water salinity EC\(_{dw}\) during *kharif* 2014

| Spacing | September | October | November | December | Average |
|---------|-----------|---------|----------|----------|---------|
| 40 m    | 11.43     | 10.53   | 9.82     | 8.10     | 9.97    |
| 50 m    | 10.28     | 8.82    | 8.24     | 7.06     | 8.60    |
| 60 m    | 8.15      | 7.54    | 7.41     | 5.79     | 7.22    |

Table 4 Monthly average leachate water salinity EC\(_{dw}\) during *rabi* 2014-15

| Spacing | January | February | March | April | Average |
|---------|---------|----------|-------|-------|---------|
| 40 m    | 11.09   | 10.85    | 9.89  | 7.89  | 9.93    |
| 50 m    | 9.51    | 9.22     | 8.35  | 6.23  | 8.33    |
| 60 m    | 8.25    | 8.02     | 7.09  | 5.5   | 7.21    |
Table 5 Crop yield under different drain spacing

| Spacing (m) | Pre-drainage (q ha\(^{-1}\)) | Post-drainage | Pooled average | Percent increase in Crop yield (%) during post-drainage |
|-------------|-------------------------------|---------------|----------------|-----------------------------------------------------|
|             | kharif 2014 (q ha\(^{-1}\)) | rabi 2014-15 (q ha\(^{-1}\)) |                |                                                     |
| 40 m        | 22                            | 53.3          | 57.5           | 55.4                                                |
|             |                               |               |                | 58.7                                                |
|             |                               |               |                | 61.7                                                |
|             |                               |               |                | 60.2                                                |
| 50 m        | 25                            | 48.8          | 52.2           | 50.5                                                |
|             |                               |               |                | 48.8                                                |
|             |                               |               |                | 52.1                                                |
|             |                               |               |                | 50.4                                                |
| 60 m        | 27                            | 44.5          | 46.7           | 45.4                                                |
|             |                               |               |                | 39.3                                                |
|             |                               |               |                | 42.2                                                |
|             |                               |               |                | 40.8                                                |

Table 6 Effect of SSD on cropping intensity

| Particulars | Total area, ha | Cultivated area, ha | Annual Cropping intensity (%) |
|-------------|----------------|---------------------|-------------------------------|
|             |                | Kharif | Rabi |                                |
| Pre-drainage 2012 | 50     | 39.5   | 34.4 | 147                            |
| Post-drainage 2015 |        | 44.5   | 41   | 171                            |

Fig. 1 Monthly amount of salt disposed during kharif 2014
Fig. 2 Monthly amount of salt disposed during rabi 2014-15

Fig. 3 Monthly nitrogen loss through drain discharge during kharif 2014

Fig. 4 Monthly nitrogen loss through drain discharge during rabi 2014-15
The percentage increase in the pooled average of the two seasons (kharif 2014 and rabi 2014-15) also calculated (Table 5) and were found to be 60.2, 50.4 and 40.8 per cent respectively for 40, 50 and 60 m spacing as compared with the pre-drainage condition. The overall maximum increase in yield was found in 40 m spacing followed by 50 and 60 m drain spacing. The improvement in paddy yield can be attributed to decrease in soil salinity (Ritzema et al., 2008) by subsurface drainage system Mathew et al., (2001), Girish (2003), Satyanarayana and Boonstra (2007).

Cropping intensity

Besides the increase in crop yield, a significant increase in the annual cropping intensity of the study area was observed and presented in Table 6. From the results it is observed that annual cropping intensity before the installation of subsurface drainage was 147 per cent which were improved to 171 per cent after the installation of subsurface drainage system. This improvement in the cropping intensity was mainly due to reclamation of the salt-affected soils and more area was brought under cultivation (Manjunatha et al., 2004).

In conclusions, the soil salinity of the study area was decreased from its initial values during post drainage conditions and maximum per cent of reduction in EC_e was found in 40 m spacing followed by 50 and 60 m drain spacing. The introduction of SSD in the study area was resulted in to increase in paddy yields to the extent of 60.2, 50.4 and 40.8 per cent in 40, 50 and 60 m respectively. Similarly, annual cropping intensity was increased from 147 to 171 percent after the installation of drainage system. Based on the comparison of the overall impact of various lateral drain spacing on reclamation, increase in crop yield and cropping intensity it can be suggest that a lateral spacing of 40 m, 50 m and 60 m can be adapted respectively depending upon the availability of funds.

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