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# Study on Yield Sustainability and Water Productivity of Groundnut on Farmers' Fields through Improved Technology under Hyper Arid Partially Irrigated Zone of Rajasthan

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## ABSTRACT

**Background:** Groundnut is an important *kharif* crop in Rajasthan and occupies important position among state crop list. However, a vast yield gap exists between potential yield and the actual yield obtained due to partial adoption of recommended package of practices by the farmers. The technology gap is a major concern in achieving optimum and sustained production. Considering the facts, present study aimed to study the effect of adaptation of improved technologies in groundnut production, water productivity and sustainability in arid zone of Rajasthan.

**Methods:** Field experiment of groundnut was carried out during four consecutive years 2016 to 2019 on farmer's field of Bikaner districts under cluster frontline demonstrations to assess the impact of improved technologies on yield sustainability, water productivity and economics of groundnut crop. The two treatments evaluated at 25 farmer's field were a) improved technologies *i.e.* high yielding varieties, seed treatment, timely sowing, optimum plant population, recommended fertilizer management, plant protection measures and irrigation management and b) farmers practice. The groundnut yield, water productivity, sustainability indices, economic returns and benefit to cost ratio of both the systems was compared using appropriate standard statistical procedure.

**Result:** The results of the present field experiment revealed that, the improved practices gave higher and sustainable yield of groundnut over years compared to farmers practice. The mean pod yield recorded (3371 kg $ha^{-1}$) with improved practices was 24.39 per cent higher than farmer's practice (2710 kg $ha^{-1}$). Similarly, improved practices had higher sustainability yield index (0.63), sustainability value index (0.47), higher water expense efficiency (74.92 kg $ha^{-1}$ $cm^{-1}$), gross water productivity (16.58 ₹ $m^{-3}$), net water productivity (11.89 ₹$m^{-3}$) and incremental benefit cost ratio (30.1) over farmers practice.


**Key words:** Groundnut, Improved technology, Sustainability value index, Sustainability yield index, Water efficiency.

## INTRODUCTION

The arid zone of India covers about 12% of the country's geographical area and occupies over 31.7 m ha of hot desert and about 7 m ha of cold desert (Moharana *et al.,* 2016). The production and life support systems in the hot regions are constrained by low and erratic precipitation (100-420 mm/ year), extreme temperature (45°C in peak of summer), high evapotranspiration (1500-2000 mm/year), poor soil fertility and physical conditions. Besides, harsh climatic conditions, soils of the region are coarse textured, poor in organic matter, available N and P (Singh *et al.* 2018) and have low water holding capacity. Furthermore, traditional methods of cultivation like use of non-descript varieties with little or no use of external inputs, over use of irrigation for growing the crops with broadcast methods further deteriorates the situation. Moreover, diverse problems with socio-economic and infrastructural backwardness do not allow the farmers to additional invest on the use of improved production technologies. In such situation various techniques for production improvement soil health sustenance such as organic farming (Aher *et al.,* 2012; Aher *et al.,* 2019; Dotaniya *et al.,* 2020), conservation agriculture (Grover and Sharma, 2011; Poddar *et al.,* 2017), no till farming (Subbulakshmi *et al.,* 2009) has been introduced. Similarly, the application of balanced fertilization (Rajput *et al.,* 2016), targeted yield based fertilization (Raghuveer *et al.,* 2017), organic nutrition (Mandale *et al.,* 2018) and micronutrient application especially zinc (Yashona *et al.,* 2018) also plays important role in maintaining sustainable crop production.

Groundnut is an important *kharif* crop grown by the farmers of Bikaner in Rajasthan (Yadav *et al.,* 2019). Though, groundnut occupies important position in the district, still a vast yield gap exists between potential yield (9 t $ha^{-1}$) and the yield obtained (1 t $ha^{-1}$) under real farming situation (Johansen and Nageswara Rao, 1996). This may be due to partial adoption of recommended package of practices by

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the groundnut growers. Technology gap is a major problem in increasing groundnut production and sustainability. So far, not much systematic effort was made to study the technological gap existing in various components of groundnut cultivation. With the available improved latest technologies, it is possible to bridge the yield gap and increase the existing production level up to certain extent (Verma *et al.,* 2012). Keeping this in view, cluster front line demonstrations were organized in participatory mode to enhance the productivity; economic returns and sustainability with the objective to analyze the yield gaps and impact of technology on sustainability in groundnut cultivation with the newly recommended package of practice.

## MATERIALS AND METHODS

The study was carried out by Krishi Vigyan Kendra, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan during *kharif* seasons of 2016 to 2019 (four consecutive years) at farmer's field in four operational villages (Benisar, Palana, Kakdaand and Gusaisar) of Bikaner district, under cluster frontline demonstration (CFLD) of National Food Security Mission (NFSM) to evaluate economic feasibility and sustainability of improved technology in groundnut crop. During the study period 40.0 ha area was covered with plot size 0.4 ha under cluster frontline demonstration with active participation of 100 farmers. Farmers were selected on the basis of group meeting. Specific skill training was given to the selected farmers about improved package and practices of groundnut cultivation. The difference between demonstration package and existing farmer's practices was given in Table 1. Soils under study were loamy sand in texture with a pH range of 8.1 to 8.6. The soils were poor in available nitrogen, medium in phosphorous and potassium and varied between 250-260, 14-18 and 220-228 kg ha$^{-1}$, respectively. Soils were deficient in micro nutrients particularly, sulphur, zinc and ferrous. In demonstration plots, inputs *viz*., quality seed of improved varieties, fertilization, herbicides, timely sowing and need based pesticides and irrigations were applied as suggested by the KVK and comparison has been made with the existing practices (Table 1).

Sowing was done in lines spaced 45 cm apart using seed rate of 80 kg ha$^{-1}$. The fertilizers were applied as per soil testing report; however, the average recommended dose of fertilizer applied in the demonstration plots was 20 kg N, 40 kg $P_2O_5$, 40 kg $K_2O$ and 25 kg S per hectare. The NPK and S fertilizers were applied through Urea, DAP, MOP and elemental S, respectively, at the time of sowing. The two sprays of $FeSO_4$ and $ZnSO_4$ were also done to mitigate the deficiency of these nutrients during growth period of crop. First irrigation was applied in demonstrated plot at 40-45 DAS, whereas farmers applied first irrigation at 10-15 DAS. The intervention of irrigation scheduling was done and reduces fifty per cent irrigation compared to farmers who applied 16-18 irrigation during crop period. The selection of sites, farmer's and layout of demonstration were done following the procedure suggested by Chaudhary (1999). The traditional practices were maintained in case of local check. The data output were collected from both CFLD plots as well as control plot and finally the extension gap, technology gap, technology index along with benefit-cost ratio were calculated as suggested by Samui *et al.* (2000). Data were recorded at harvest from demonstration blocks and farmers practice blocks. The data were analyzed for different parameters using following formulae suggested by Prasad *et al.* (1993).

Extension gap = Demonstration yield - Farmers' practice yield

Technology gap = Potential yield - Demonstration yield

Technology index =

$$\frac{\text{Potential yield - Demonstration yield}}{\text{Potential yield}} \times 100$$

Sustainability indices (sustainability yield index and sustainability value index) were work out using formulae given by Singh *et al.* (1990).

$$\text{SYI/SVI} = \frac{Y\text{-}O}{Y_{max}}$$

Where

Y = Estimated average yield/ net return of practices over the year.

O = Standard deviation.

$Y_{max}$ = Maximum yield/maximum net return.

The water expense efficiency (WEE), gross water productivity (GWP) and net water productivity (NWP) were calculated using formulae given by Cook *et al.* (2006).

$$\text{WEE} = \frac{\text{Total yield (kg ha}^{-1}\text{)}}{\text{Total water expense (cm)}}$$

$$\text{GWP} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Total water expense (cm)}}$$

$$\text{NWP} = \frac{\text{Net return (kg ha}^{-1}\text{)}}{\text{Total water expense (cm)}}$$

The obtained data were further analyzed for standard deviation and coefficient of variation as per standard procedure given by Panse and Sukhatme (1961).

## RESULTS AND DISCUSSION

### Pod yield

Pod yield (dry weight) of groundnut varied from 2330-4590 kg ha$^{-1}$ under improved technologies and 1290-4234 kg ha$^{-1}$ with farmers practices (Table 2). Four year mean pod yield of improved practices of groundnut was 3371 kg ha$^{-1}$ which was 24.39 per cent higher than four years mean yield of farmer's practice (2710 kg ha$^{-1}$). The higher pod yield under demonstrations could be attributed to adoption of improved technology *viz*., spacing, micronutrient application, weed management, nutrient management, improved variety *etc.* created a favorable impact on nutrient uptake and growth which resulted in enhanced groundnut productivity. Year wise variation in pod yield was observed due to variation in the

**Table 1:** Comparison between improved and existing practices of groundnut cultivation during study.

| Particulars | Practices of groundnut cultivation | |
|---|---|---|
| | Improved practices | Farmers' practices |
| Farming situation | Irrigated | Irrigated |
| Variety | HNG-69 | Local seed from Mundi |
| Time of sowing | First or second week of June | First or second week of May |
| Method of sowing | Line sowing with row spacing of 45 cm. | Line sowing with row spacing of 30 cm. |
| Seed treatment | Carbendazim50 W.P.@2.0 g and Imidacloprid 17.8 S.L. @ 3.0 ml $kg^{-1}$ seed. | No seed treatment and sometime use of chloropyrephos 20 EC @ 5-10 ml $kg^{-1}$ seed. |
| Seed rate | 80 kg $ha^{-1}$ | 160 kg $ha^{-1}$ |
| Fertilizer dose | NPKS Zn (20:40:40:25: 25) kg $ha^{-1}$ | NPKS Zn (56:24:00:25:00) kg $ha^{-1}$ |
| Micronutrient | Two sprays of 0.5 % $FeSO_4$ with citric acid and $ZnSO_4$ with lime were done due to deficiency occurring during growth period of crop. | $ZnSO_4$ applied with irrigation water. |
| Irrigation | First at 40-45 DAS and then irrigated 8-9 times. | First at 10-15 DAS and then continuously applied 16-18 irrigations. |
| Weed management | Application of pre-emergence herbicide pendimethalin @ 1.00 kg $ha^{-1}$. If the weeds emerge after planting, imaze--thapyr @ 40 g/ha may be sprayed 30 days after sowing. | Application pendimethalin @ 1.00 kg $ha^{-1}$ as pre emergence but applied with irrigation water. |
| Plant protection | Approaches of Integrated pest and disease management for the management of pest and diseases. | Injudicious use of pesticides and fungicides. |

**Table 2:** Effect of production practices on pod yield, net return, SYI and SVI of groundnut.

| Particulars | 2016 | | 2017 | | 2018 | | 2019 | | Pooled | |
|---|---|---|---|---|---|---|---|---|---|---|
| | IT | FP | IT | FP | IT | FP | IT | FP | IT | FP |
| Pod yield (kg $ha^{-1}$) Max. | 4590 | 4233.9 | 4250 | 3920 | 3800 | 3378 | 4090 | 3620 | 4590 | 4233.9 |
| Pod yield (kg $ha^{-1}$) Min. | 3060 | 2382.6 | 2330 | 1520 | 2800 | 1909 | 2640 | 1290 | 2330 | 1290 |
| Mean pod yield (kg $ha^{-1}$) | 3684 | 3137 | 3180 | 2578 | 3426 | 2795 | 3196 | 2332 | 3371 | 2710 |
| SD | 365 | 441 | 581 | 727 | 282 | 454 | 493 | 777 | 485 | 678 |
| CV (%) | 9.9 | 14.1 | 18.3 | 28.2 | 8.2 | 16.2 | 15.4 | 33.3 | 14.4 | 25.0 |
| Net return (₹ $ha^{-1}$) Max. | 108840 | 98381 | 103625 | 93500 | 116500 | 100730 | 141615 | 122220 | 141615 | 122220 |
| Net return (₹ $ha^{-1}$) Min. | 61410 | 40991 | 41225 | 15500 | 76500 | 41978 | 78540 | 20865 | 41225 | 15500 |
| Mean net return (₹ $ha^{-1}$) | 80739 | 64379 | 68837 | 49898 | 101540 | 77393 | 102726 | 66175 | 88461 | 64461 |
| SD | 11310 | 13685 | 18883 | 23612 | 11295 | 18148 | 21446 | 33791 | 21605 | 25174 |
| CV (%) | 14.0 | 21.3 | 27.4 | 47.3 | 11.1 | 23.5 | 20.9 | 51.1 | 24.4 | 39.1 |
| SYI | 0.72 | 0.64 | 0.61 | 0.47 | 0.83 | 0.69 | 0.66 | 0.43 | 0.63 | 0.48 |
| SVI | 0.64 | 0.52 | 0.48 | 0.28 | 0.78 | 0.59 | 0.57 | 0.27 | 0.47 | 0.32 |

IT- Improved technology; FP- Farmers practice; SD- Standard deviation; CV- Coefficient of variation; SYI- Sustainability yield index; SVI- Sustainability value index.

environmental conditions prevailed during that particular year. Narolia *et al* (2013) also reported that improved package of practices has shown positive effect on yield potentials of different crops. Similarly, improved practices recorded higher mean water expanse efficiency (280.9 kg ha-$cm^{-1}$) as compared to farmer's practice. The improved technologies played role towards enhancing the nutrient availability, water use efficiency, nutrient use efficiency which improved the yield. The results of Meena *et al.* (2012) are in conformity with these findings. Singh *et al.* (2013) also found the role of improved seed in enhancing the crop yield. Recently, the enhancement in yield of moth bean under improved technologies of CFLD has already been reported by Reager *et al.* (2020).

## Adoption gap

The adoption gap is a key factor influencing the productivity of groundnut (Table 3). The gap analysis was done by evaluating the extension gap, technology gap and technological index to measure the magnitude of adoption technology. The extension gap is a parameter to know the yield difference between the demonstrated technology and farmer's practice and observed data further indicated that extension gap varied from 546 to 864 kg $ha^{-1}$ with an average of 661 kg $ha^{-1}$. This indicated a wide gap between the demonstrated improved technologies and the farmer's practice. Technological gap is a measure of difference between potential yield and yield obtained under improved technology demonstration. It has a great significance than

**Table 3:** Effect of improved technology demonstrations on pod yield, water expense efficiency and gap indices of groundnut.

| Year | Pod yield (kg ha$^{-1}$) | | Yield increase over FP | Potential yield | Extension gap | Technology gap | Technology index |
|---|---|---|---|---|---|---|---|
| | IT | FP | (%) | (kg ha$^{-1}$) | (kg ha$^{-1}$) | (kg ha$^{-1}$) | (%) |
| 2016 | 3684 | 3137 | 17.4 | 4000 | 546 | 316 | 7.9 |
| 2017 | 3180 | 2578 | 23.3 | 4000 | 601 | 820 | 20.5 |
| 2018 | 3426 | 2795 | 22.6 | 4000 | 631 | 574 | 14.4 |
| 2019 | 3196 | 2332 | 37.1 | 4000 | 864 | 804 | 20.1 |
| Mean | 3371 | 2710 | 25.1 | 4000 | 661 | 629 | 15.7 |

IT- Improved technology; FP- Farmers practice.

**Table 4:** Effect of improved technology demonstrations on water productivity parameters of groundnut.

| Year | Effective rainfall | Water productivity parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Water expense (mm) | | WEE (kg ha-cm$^{-1}$) | | GWP (₹ m$^3$) | | NWP (₹m$^3$) | |
| | (mm) | IT | FP | IT | FP | IT | FP | IT | FP |
| 2016 | 347.1 | 797 | 977 | 46.21 | 32.11 | 14.33 | 9.95 | 10.13 | 6.59 |
| 2017 | 269.5 | 720 | 900 | 44.19 | 28.66 | 14.36 | 9.32 | 9.57 | 5.55 |
| 2018 | 305.3 | 755 | 935 | 45.36 | 29.88 | 18.14 | 11.95 | 13.44 | 8.27 |
| 2019 | 262.8 | 713 | 893 | 44.84 | 26.12 | 19.50 | 11.36 | 14.41 | 7.41 |
| Mean | 296.2 | 746 | 926 | 45.15 | 29.19 | 16.58 | 10.65 | 11.89 | 6.96 |

IT- Improved technology; FP- Farmers practice; WEE- Water expense efficiency; GWP- Gross water productivity; NWP- Net water productivity.

other parameters as it indicates the constraints in implementation of technology and drawbacks in our package of practices. This also reflects the poor extension activities, which resulted in less adoption of improved management technologies by the farmers. This gap can be bridge by strengthening the extension activities and further on farm research to improve adoption of package of practices. Technology index is dependent on technology gap and is a function expressed in per cent. Technology index of four years of study varied from 7.9 to 20.5 per cent with an average of 15.7 per cent. The very low technology index (7.9) during the year 2016 could be due to adoption of improved technology, favorable climatic conditions and no insect pest and disease incidences. High technology index shows a poor adoption of package of practices and improved technologies by the farmers. Similar findings with respect to front line demonstrations were observed by Singh *et al.* (2018) and Reager *et al.* (2020) in chickpea and moth bean crops in arid zones of Rajasthan.

### Sustainability

A perusal of data (Table 2) revealed that higher standard deviation (SD) and coefficient of variation (CV) in yield were observed under farmer's practices over improved technology demonstrations in all the four years. This may be due to more variation in the yield of farmer's practice from farmer to farmer and least variation in improved technology demonstrations. However, the maximum values of sustain-ability yield index (SYI) and sustainability value index (SVI) were found under improved technology than farmer's practices. The mean SYI and SVI over these four years under improved technology varied from 0.611 to 0.827 and 0.482 to 0.638, whereas, corresponding values under farmers practice were 0.430 to 0.693 and 0.265 to 0.588, respectively. Pooled data further revealed that SYI and SVI increased to the tune of 31.25 and 46.88 per cent over farmers practice. This shows that the improved technology is more sustainable as compared to farmer's practice. Similar results have been reported by Narolia *et al.* (2013) in mustard and Reager *et al.* (2020) in moth bean.

### Water productivity

In arid climatic conditions, weather parameter values of temperature, relative humidity and evaporation play an important role in relation to water productivity. Data in Table 4 showed higher water expense efficiency (WEE), gross water productivity (GWP) and net water productivity (NWP) with improved technologies than farmers practice for all the four years. The maximum values of four year mean WEE (45.15 kg ha-cm$^{-1}$), GWP (16.58 ₹ m$^3$) and NWP (11.89 ₹m$^3$) were found under improved technology and with an increase of 54.68, 55.68 and 70.83 per cent, respectively over farmer's practices. This may be due to lower yield obtained and mismanagement of water in the farmers practice. This indicates that the improved technology is more efficient in water management as compared to farmers practice. Narolia *et al.* (2013) also experienced the higher productivity and sustainability of mustard under improved water management technology in Chambal command. The higher water productivity in moth bean with improved techniques has been recorded in arid zone of Rajasthan (Reager *et al.,* 2020).

### Economics

Yield, cost of variable inputs and sale price of produce determine the economic returns and these vary from year

**Table 5:** Effect of improved technology demonstrations on economics of groundnut.

| Year | Cost of inputs (₹ ha$^{-1}$) | | Additional cost in IT (₹ ha$^{-1}$) | Sale price (₹ q$^{-1}$) | ross return (₹ ha$^{-1}$) | | Additional return in IT (₹ ha$^{-1}$) | Effective gain (₹ ha$^{-1}$) | IBCR |
|---|---|---|---|---|---|---|---|---|---|
| | IT | FP | | | IT | FP | | | |
| 2016 | 33450 | 32870 | 580 | 3100 | 114189 | 97249 | 16940 | 16360 | 29.2 |
| 2017 | 34500 | 33900 | 600 | 3250 | 103337 | 83798 | 19539 | 18939 | 32.6 |
| 2018 | 35500 | 34400 | 1100 | 4000 | 137040 | 111793 | 25247 | 24147 | 23.0 |
| 2019 | 36300 | 35250 | 1050 | 4350 | 139026 | 101425 | 37601 | 36551 | 35.8 |
| Mean | 34938 | 34105 | 833 | 3675 | 123398 | 98566 | 24832 | 23999 | 30.1 |

IT- Improved technology; FP- Farmers practice; IBCR- Incremental benefit cost ratio.

to year as the cost of input, labour and sale price of produce changes from time to time (Table 5). The year wise additional returns from improved technologies over farmer's practice varied from ₹16940 ha$^{-1}$ to ₹37601 ha$^{-1}$ with an average additional return of ₹24832 ha$^{-1}$. The mean additional cost of input of all the demonstrations for four years was ₹833 ha$^{-1}$. The higher sale price of produce in spite of low production and lower additional cost of input during year 2019 gave highest additional return (₹37601 ha$^{-1}$) under improved technologies than farmer's practice. The mean incremental benefit cost ratio (IBCR) fetched was 30.1 and it showed the positive impact of improved technology. The highest IBCR (35.8) was observed in the year of 2019 and least (23.0) in 2018. The highest IBCR under these treatments is a result of higher grain yield, less cost of input and a good return. The results are in conformity with the earlier findings of Sonawane *et al.* (2016) who reported higher IBCR of groundnut under application of mechanization.

## CONCLUSION

The traditional methods of cultivation like use of non-descript varieties with little or no use of external inputs, over use of irrigation for growing the crops with broadcast methods not only reduces the crop yield but further deteriorates the soil health. It is therefore essential to ensure the participation of the farmers to the use of improved production technologies. The results of present investigation are very promising and has potential to eliminate general agricultural issues such as reduction in crop yield, deteriorating soil health, socio-economic issues of farmer's and farming community *etc*. The pod yield under improved practices was found 24% higher than farmer's practice. The improved practices showed higher sustainability yield index (0.63), sustainability value index (0.47), higher water expense efficiency (74.92 kg ha$^{-1}$ cm$^{-1}$), gross water productivity (16.58 ₹m$^{-3}$), net water productivity (11.89 ₹m$^{-3}$) and incremental benefit cost ratio (30.1) over farmers practice. The integration of improved production technologies proved better in all aspects such as yield, water use efficiency, sustainability and crop economics. The use of improved production technologies for various crops as per the guidelines of respective agencies is recommended for better productivity and sustainability.

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