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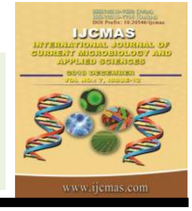

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Effect of Different Levels of Gypsum on Pattern of Moisture Use and Aggregation in Vertisols under Soybean-Chickpea Sequence

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A B S T R A C T

A field investigation relating to "Effect of levels of gypsum on pattern of moisture use and aggregation in Vertisols under soybean-chickpea - sequence" was conducted at Agronomy farm, College of Agriculture, Nagpur. The field experiment was laid out in randomized block design (RBD) with a seven treatments replicated thrice. Treatments consisted of 1, 1.5, 2, 2.5, 3, 5 t gypsum per hectare and a control. The samples were taken from (0-30 cm) and (30-60 cm) depth for conducting study. The surface soil of experimental site was slightly alkaline in reaction clayey in texture, medium in organic carbon (6.21 kg^{-1}), low in available nitrogen (206.98 kg), medium in phosphorus (19.23 kg ha^{-1}), high in potassium (503.00 kg ha^{-1}) poor in hydraulic conductivity (1.06 cm ha^{-1}). The CEC of surface and subsurface soil was 52.16 and 53.70 [cmol (p^{+}) kg^{-1}] and Ca/Mg ratio of was 1.30 and 1.21 respectively. Application of gypsum does not markedly affect the cumulative moisture use during and at different percent growing season of soybean and chickpea. However MUE of soybean significantly increased with increasing level of gypsum. Higher MUE was found with T_6 (3 t gypsum ha^{-1}) but T_3 (1.5 t gypsum ha^{-1}) is enough to increase MUE of soybean significantly over no gypsum. Increasing level of gypsum also increase the MUE of chickpea.

Keywords

Gypsum, Vertisols, Moisture, Soybean, Chickpea

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Introduction

Vertisols are dark, montmorillonite rich clays, characteristics shrinking and swelling properties and have high clay content (>30 % up to at least 50 cm from surface) and produce typical cracks (at least 1 cm wide reaching a depth of 50 cm or more). Vertisols and associated vertic soil in peninsular India occurs mostly extending from 8º45' to 26 º0' N latitude and 66º0' to 83º45' E longitude covering an area of 73 million ha. The area occupied by Vertisols constitutes nearly 22.2% of total geographical area of India out of which Maharashtra account for 29.9 million hectares (Murthy, 1982).

The unique properties special to vertisols are high clay content, volume changes with moisture, cracks that split and merge periodically and evidence of soil movement in the form of slicken slides and of wedge shaped structural aggregates that are tilted with an angle from the horizon. The shrink-swell phenomenon which is responsible for the genesis and behavior of vertisols is a complex, dynamic and yet incompletely understood set of processes (Gokhan and Aksoy, 2007).

The poor structural stability of Vertisols particularly during the monsoon season render the agricultural activity difficult, the low saturated hydraulic conductivity causes water logging. As a result vast land remain vacant particularly during monsoon season (Sen, 2003).

Increases in ESP and EMP with depth have adversely affected the hydraulic and other properties important for crop growth. Saturation of these soils, not only with Na^{+} ions but also with Mg^{2+} ions leads to greater dispersion of clay, which is the opposite effect from that saturation with Ca^{2+} ions, which leads to the blocking of small pores in the soil. In other words, Mg^{2+} ions are less efficient than Ca^{2+} ions in flocculating soil colloids. However due to high evaporative demand for soil water in the semi-arid climatic condition, maintenance of a proper Ca/Mg ratio in the soil solution becomes difficult because Ca^{2+} ion get precipitate as $CaCO_3$ result in depletion of Ca^{2+} ions from the soil solution (Balpande *et al*., 1996). The Vertisols have enough $CaCO_3$ but the soluble calcium concentration in the saturation extract of the many Vertisols were is 0.6 to 3.6 mmol L^{-1} and this amount is not enough to inhibit the swelling of smectite by contracting the diffuse double layer. This indicates the inertness of calcite to inhibit the swelling of smectite (Balpande *et al.,* 1997).

Under rainfed condition yield of crop depends primarily on the amount of rain stored in soil profile and extend to which this water is released during crop growth. More over both retention and release of soil water are governed by the nature and content of clay minerals, and also by the nature of exchangeable cations.

The exchangeable polyvalent cations (e.g. Ca) near clay surfaces reduce the thickness of the diffuse double layer. The reduction in repulsive forces acting between clay particles (Emerson 1983) helps for the flocculation of clays and increased resistance to dispersion (the Schultze- Hardy Rule). Calcium rather than Mg or K on the exchange complex was associated with stable aggregates in Australian subsoils (Emerson and Bakker 1973). Pojasok and Kay (1990) found aggregate stability to increase with Ca concentrations in soil solution.

In the view of above consideration, field experiment entitled “Effect of gypsum on moisture availability in Vertisols under soybean gram sequence” was conducted with following objectives, To study the effect of gypsum on moisture use pattern during the cropping period under soybean and chickpea sequence.

Materials and Methods

The field investigation in relation to “Effect of levels of gypsum on pattern of moisture use and aggregation in Vertisols under soybean-chickpea sequence”, was conducted during Kharif and rabi season at Agronomy Farm, College of Agriculture, Nagpur. The details of material used and methods adopted during the period of investigation are given in this chapter under appropriate heads.

Experimental site

The field experiment entitled “Effect of levels of gypsum on pattern of moisture use and aggregation in Vertisols under soybean-chickpea sequence”, was carried out at Extra Assistant Director (EAD) farm, College of

Agriculture Nagpur. The field selected for conducting experiment was fairly uniform and leveled (Table 1).

Soil of experimental area

The soil under the experimental study was fine montmorillonite of Typic Haplustert. In order to study the physical and chemical properties soil samples were taken from 0-30 and 30-60 cm depth with the help of screw auger from randomly selected spots over the experimental field before sowing. The soil of the experimental field was clay in texture. The result of the chemical analysis data indicate that soil was low in available nitrogen, medium in available phosphorus, very high in available potassium, medium in organic carbon, low in available sulphur soil pH was 8.10 and electrical conductivity recorded 0.20 dS m^{-1}

Climate and weather conditions

Nagpur is situated at 21º 10' North latitude and 19º 19' East latitude at elevation of 321.26 meter above sea level and lies under sub-tropical zone. Nagpur is characterized by hot and dry summer and fairly cold winter. This area shows wide diurnal fluctuation in temperature. The maximum and minimum temperature ranged from 43.3 to 8.5ºC respectively. Whereas relative humidity varied from 13% to 90%. During the crop growth period mean annual precipitation was about 928.8 mm and major amount of it is received from June to December within 46 rainy days.

Experimental details

Design of experiment and treatments

The experiment was laid out in randomized block design (RBD) with seven treatments each replicated thrice, the detail of treatment are presented below.

Treatment details

T_1: Control (no Gypsum)
T_2: 1.0 t ha^{-1} gypsum
T_3: 1.5 t ha^{-1} gypsum
T_4: 2.0 t ha^{-1} gypsum
T_5: 2.5 t ha^{-1} gypsum
T_6: 3.0 t ha^{-1} gypsum
T_7: 5.0 t ha^{-1} gypsum

Fertilizer application

The fertilizer application was done as per recommended doses (experimental details) for both the crop. Nitrogen and phosphorus were applied through Urea and SSP respectively, fertilizers doses were applied to different plot at the time of sowing.

Methodology for gypsum application

Gypsum in powder form was applied to different plots as per treatments before sowing of soybean crop. The proper care was taken for equal mixing of gypsum in surface soil and for that after application of gypsum to soil it was equalized by turning surface soil.

Soil sampling and processing

Initial treatment wise soil samples from (0-30 cm) and (30-60 cm) depth after harvest of soybean were collected. The soil samples were dried in shade and gently grind with wooden pestle and mortar and sieved through 2mm sieve. These samples were stored in polythene bags and were subsequently analysed for various properties.

Collection of soil sample for soil moisture study

The treatment wise soil samples were collected with the help of screw auger from (0-30 cm) and (30-60 cm) depth between the two rows at an interval of 15. These samples were immediately put in pre weighed aluminum boxes for determination of moisture content by gravimetric method.

Determination of moisture use efficiency (MUE)

Soil moisture studies

The initial weights of the soil sample along with aluminum boxes were recorded immediately on electronic balance. Then the aluminum boxes along with soil samples were kept in hot air oven at 105ºC up to constant weight obtained and final dry weights were recorded. The soil moisture was determined by gravimetric method. The moisture percent was calculated by using following formula.

Gravimetric moisture content (%) = $\frac{w_1 - w_2}{w_2} \times 100$

w_1: Initial weight of soil
w_2: Oven dry weight of soil

Soil moisture in profile during different period of crop growth

Soil moisture up to depth 60 cm was calculated as follows.

1. Soil moisture (mm) in 0-30 cm layer depth = $\frac{\%\text{ Gravimetric moisture x bulk density}}{100} \times 300$
2. Soil moisture (mm) in 30-60 cm layer depth = $\frac{\%\text{ Gravimetric moisture x bulk density}}{100} \times 300$

Moisture use by crop during a period

Moisture use by crop during a period was calculated as follows:

Where,

Moisture use (mm) during a period	=	Soil moisture (mm) up to 60 cm depth at initial stage	+	Rainfall during a period (mm)	-	Soil moisture (mm) up to 60 cm depth at subsequent sampling

Soil moisture up to 60 cm depth at the first period is considered as initial soil moisture for second period and likewise.

Total moisture use (mm) = $\sum_{i=1}^{n}$ moisture use during different periods.

Percent growing season of the crop

Moisture use during different periods (percent growing season) at different intervals of soil sampling was expressed in terms of percent growing season of the crop which was calculated on the basis of duration of crop.

Percent growing season =

$$\frac{\text{Number of days of sampling}}{\text{Duration of the crop}} \times 100$$

Moisture use efficiency (MUE)

Moisture use efficiency for each treatment was calculated on the basis of economic yield of the crop and total moisture use by that crop in given treatment by Michael and Ojha, (1983).

MUE (kg ha^{-1} mm^{-1}) =

$$\frac{\text{Crop yield (kg ha}^{-1})}{\text{Total moisture use (mm)}}$$

Results and Discussion

The present investigation entitled "Effect of levels of gypsum on pattern of moisture use and aggregation in Vertisols under soybean-chickpea-sequence" were carried out by conducting a field trial of soybean and chickpea. The results obtained and inferences drawn were discussed under following heads.

2.1 Physical and chemical properties of vertisols of the experimental site

2.2 Moisture content in soil during cropping period.

2.3 Moisture use and its use pattern by crops.

2.4 Assessment of moisture availability period (growing period).

Physical and chemical properties of vertisols of the experimental site

The soil of the experimental field was clay in texture. The result of the chemical analysis indicated that soil was low in available nitrogen, medium in available phosphorus, very high in available potassium, medium in organic carbon, low in available sulphur soil pH was 8.10 and electrical conductivity recorded 0.20 dS m^{-1}

Moisture content in soil during cropping period

Moisture content in soil largely depends on climatic factors i.e. rainfall pattern, rate of PET and storage in soil. Soil moisture content (gravimetric) at 0-30cm and 30-60 cm depth were determined. Moisture percentage in soil was increased from 6th July 2009 to 21st July 2009 due to occurrence of rain during that period. After that less moisture was observed in soil up to 20th August and it suddenly increased on 5th September 2009 due to heavy rain. After that it decreased upto 7th October 2009. Further at 23rd October moisture content was found to increase due to irrigation for the seedbed preparation of the chickpea crop. During cropping period highest moisture percentage was found at 21 st July in the range of 37.18 to 40.31% in surface and 35.21 to 39.18% in sub surface soil. Lowest moisture percentage at surface soil was found at 7 th October 2009 in the range of 16.48 to 21.19% and at subsurface soil was found in the range of 16.49 to 20.18 percent. It was also noticed that decrease in moisture percentage in surface soil is much faster than sub-surface soil, which may be due to utilization of moisture by the crop (Kadiappa *et al.,* 1974) and more evaporation from the surface. The climatic moisture balance and actual moisture storage is detected. The actual moisture storage is less than the climatic moisture balance.

Moisture use and its use pattern by crops

Total moisture use by soybean crop was determined considering the rainfall and actual soil moisture availability from sowing to harvesting stage.

Cumulative moisture use (mm) at different percent of growing season of soybean and chickpea

The data pertaining to cumulative observed moisture use at different percent of growing season of soybean (JS-335) and chickpea (JAKI -9218) under various treatment are presented in table 2(a) and 2(b). Moisture use value at percent growing season of crop were calculated for each treatment which showed little variation in cumulative moisture use at different percent growing season of crop.

It is seen that, soybean crop used moisture in range of 613.6 to 691.6 mm and chickpea crop used moisture in range of 169.14 to 224.78 mm within the various levels of gypsum.

Moisture use decreases with increasing levels of gypsum. Highest moisture use recorded in control. The lower moisture use was recorded in T_7 (5.0 t gypsum per hectare) followed by T_6 (3 t gypsum per hectare) and T_3 (1.5 t gypsum per hectare)

Total moisture use during growing season of soybean decreased with increased level of gypsum which indicates better utilization and storage soil moisture during the growth period.

For soybean cumulative moisture use under different treatment varied between 32.55 to 35.36 % at 33.3 percent growing season of crop, 36.69 to 42.73% at 50.53 percent growing season of crop as against 76.79 to 87.40% at 83.87 percent growing season of crop indicating about 85 percent of total moisture use during 0-85 per cent growing season of crop and less moisture used during later period.

In case of chickpea cumulative moisture use under different treatment varied between 28.07 to 32.80 % of total moisture use at 28.12 per cent growing season of crop. Cumulative moisture use varied between 62.64 to 79.41 % at 64.84 percent growing season, as against 82.76 to 92.19 percent at 76.56 percent growing season indicating about 90 percent of total moisture use during 0-76 percent growing season of crop and less moisture used during later period.

Patil (1987) noted that 64.3 to 65.9 % of total moisture use for different treatment by end of 70 percent of growing season. Kalane *et al.*, (1990) and Dhopte (1994) reported linear increase of moisture use with percent growing season of hybrid Sorghum CSH-9. Differences in consumptive use and water use efficiency in different crops may be due to genetic variability in plant type and yield potential.

In soybean maximum moisture use was recorded in T_1 (no gypsum) treatment (691.6 mm), followed by T_2 (648.0), T_4 (641.9 mm) T_5 (628.3 mm), T_3 (626.3 mm) and least moisture use recorded by T_7 (5 t gypsum ha^{-1}) treatment (613.6). However not much variation in total moisture use was found in various treatments.

In case of chickpea total moisture used ranged between 169.4 to 224.78 mm, where maximum moisture use was recorded by T_2 (1 t gypsum ha^{-1}) treatment followed by T_6 (199.49 mm), T_5 (197.79 mm) and least moisture use recorded by T_7 (169.14). However not much variation in total moisture use was found under different treatment.

Moisture use by soybean and chickpea during different period of percent growing season of crop

Calculated moisture use during different period of percent growing season of crop presented in table 2(a) and 2(b). The data in table 2(a) showed that, in soybean cumulative moisture use during different percent of growing season of crop i.e. 0 to 33.3%, 33.3 to 67.74% and 67.74 to 100.0% growing season varied over narrow range 208.97 to 242.88 mm, 192.35 to 224.08 mm and 187.61 to 256.37 mm respectively under different treatments.

This showed that moisture use during early period i.e. 0 to 67.74% growing season was more and it further decreased during 67.74 percent growing season of soybean crop under all treatments.

The data in table 2(b) showed that in chickpea cumulative moisture use during different percent of growing season of crop i.e. 0 to 28.12%, 28.12 to 76.56% and 76.56 to 100.0% growing season varied over 51.1 to 65.45 mm, 94.91 to 135.87 mm and 13.2 to 30.4 mm respectively under different treatments. This revealed that moisture use during early growth i.e. 0 to 28.12% growing season is less over mid period i.e. 28.12 to 76.56 per cent growing season of crop and it further decreased during 76.56 to 100.0 percent growing season of gram under all treatment. This variation in moisture use during different period in growing season of crop was mainly due to varied moisture requirement of crop during different crop growth stages and climatological factors.

Total moisture use and moisture use efficiency (MUE) of soybean and chickpea

Considering total productivity and total moisture use of soybean and chickpea, moisture use efficiency was calculated and the data pertaining to moisture use efficiency (MUE kg ha^{-1} mm^{-1}) under different treatment are presented in table 2.

In soybean maximum moisture use was recorded under T_1 (no gypsum) and lowest moisture use was recorded under treatment T_7 (5 t gypsum ha^{-1}). Moisture use slightly decreases due to increase in level of gypsum.

Data indicated that there was significant effect of different gypsum treatments on the seed yield of soybean. Treatment T_6 (3 t gypsum ha^{-1}) recorded the highest soybean seed yield (19.25 q ha^{-1}) which was at par with treatment T_7 (5 t gypsum ha^{-1})

Application of 1.5t gypsum per hectare (T_3) gave 18.64 q ha^{-1} seed yield of soybean which was superior over no gypsum (T_1) and 1.0 t gypsum per hectare (T_2) and found at par with increasing levels of gypsum. Percent increase in the yield of soybean due to increasing level of gypsum was found in the range of 7.3 t 19.3 percent over no gypsum application (Table 3).

Application of gypsum significantly increased the MUE of soybean, maximum MUE 3.10 kg ha^{-1} mm^{-1} was found under treatment T_6 (3 t gypsum ha^{-1}) which is significantly superior over treatment T_1 (no gypsum) and T_2 (1 t gypsum ha^{-1}) and at par with treatment T_7, T_5, T_4 and T_3. This indicated that treatment T_3 low level of gypsum (1.5 t ha^{-1}) was sufficiently maintaining electrolyte concentration in percolating water which helps in stabilization of soil structure to receive good yield and moisture use efficiency.

Table.1 Location and treatment details

1	Location	:	Agronomy Farm, College of Agriculture, Nagpur.
2	Name of the crop (Kharif)	:	Soybean (JS-335)
	(Rabi)	:	Chickpea (JAKI -9218)
3	Design of experiment	:	Randomized Block Design (RBD)
4	No. of Treatments	:	7
5	No of Replication	:	3
6	Total no. of plots	:	21
7	Plot size	:	Gross 6 x 5.4 m
		:	Net 4x3.6 m
8	Spacing (soybean)	:	30 x 5 cm^2
	(Chickpea)	:	30 x 10 cm^2
9	Fertilizer dose (soybean)	:	30:75:00 NPK kg ha^{-1}
	(Chickpea)	:	25:50:00 NPK kg ha^{-1}
10	Seed rate (soybean)	:	80 kg ha^{-1}
	(Chickpea)	:	100 kg ha^{-1}
11	Method of sowing (soybean)	:	Drilling
	(Chickpea)	:	Drilling

Table.2(a) Moisture use by soybean during different period of percent growing season of soybean

Treatments	Moisture use (mm) during different period of % growing season			Cumulative Moisture use (mm) at different growing season of crop.		
	0-33.3%	33.3-67.74	67.74-100.0%	33.3%	67.74%	100.0%
T_1	242.88	192.35	256.37	242.88	435.23	691.6
T_2	226.56	224.08	197.36	226.56	450.64	648.0
T_3	215.13	210.8	200.37	215.13	425.93	626.3
T_4	208.97	211.15	221.78	208.97	420.12	641.9
T_5	222.17	208.44	197.69	222.17	430.61	628.3
T_6	214.22	209.27	196.91	214.22	423.49	620.4
T_7	214.84	211.15	187.61	214.84	425.99	613.6

Table.2(b) Moisture use by gram during different percent of growing season of chickpea

Treatments	Moisture use (mm) during different period of % growing season			Cumulative Moisture use (mm) at different growing season of crop.		
	0-28.12%	28.12-76.56%	76.56-100%	28.12%	64.84%	100%
T_1	51.1	94.91	30.4	51.1	110.51	176.41
T_2	63.1	135.87	25.81	63.1	143.00	224.78
T_3	51.86	105.13	25.31	51.86	125.41	182.3
T_4	57.08	121.51	16.15	57.08	154.72	194.74
T_5	61.33	117.17	19.29	61.33	150.81	197.79
T_6	65.45	113.57	20.47	65.45	151.68	199.49
T_7	55.41	100.53	13.2	55.41	134.33	169.14

Table.3 Effect of gypsum on seed yield and MUE of soybean and chickpea

Treatments	Soybean			Chickpea		
	Seed yield (q ha^{-1})	Total moisture use (mm)	MUE (kg ha^{-1} mm^{-1})	Seed yield (q ha^{-1})	Total moisture use (mm)	MUE (kg ha^{-1} mm^{-1})
T_1	15.53	691.6	2.24	9.56	176.41	5.42
T_2	16.75	648.0	2.58	10.69	224.78	4.75
T_3	18.64	626.3	2.97	11.11	182.3	6.09
T_4	18.62	641.9	2.90	11.38	194.74	5.84
T_5	18.73	628.3	2.98	11.71	197.79	5.92
T_6	19.25	620.4	3.10	11.69	199.49	5.85
T_7	18.85	613.6	3.07	12.22	169.14	7.22
SE (m)	0.13	-	0.54	0.13	-	0.07
C.D. at 5%	0.41	-	1.69	0.42	-	0.21

The highest moisture use efficiency under treatment T_7 was might be due to better physical condition, which intern helps in increasing the yield. Similar effect of gypsum was also noted by Sagare *et al.,* (2001), in Vertisols of Purna valley.

In chickpea total moisture use recorded under different treatment varied between 169.14 mm to 224.78 mm. Maximum moisture use recorded under treatment T_2 (1.0 t gypsum ha^{-1}) 224.78 mm and minimum moisture use recorded under treatment T_7 (5 t gypsum ha^{-1}). However, moisture use slightly decreases with increase levels of gypsum while variation in total moisture use was not much.

Highest seed yield of the chickpea 12.22 q ha^{-1} recorded under treatment T_7 (5 t gypsum ha^{-1}) followed by treatment T_5 and minimum seed yield of the chickpea (9.56 q ha^{-1}) recorded under treatment T_1 (no gypsum). Gypsum application at the rate of 1.5 t per hectare (T_3) gave significantly higher yield over no gypsum treatment (T_1).

The maximum moisture use efficiency in chickpea was registered under treatment T_7 (7.22 kg ha^{-1} mm^{-1}) as against minimum recorded in control T_2 (4.75 kg ha^{-1} mm^{-1}). The maximum MUE recorded in T_7 mainly due to the maximum yield recorded under same treatment as there was not much variation found in moisture use. The MUE of chickpea recorded under Vertisol varied over 5.50 to 4.61 kg^{-1} ha^{-1} mm^{-1} as observed by Hajare *et al.*, (1997).

Assessment of moisture availability period (Growing period)

The data presented in figure 1 indicated that the length of LGP of these soils was 175 days for the year 2009-10. The pattern of rainfall and PET and ½ PET indicated humid period of 119 days and moist period of 140 days, which was from June to mid of October. The average soil moisture content across the 15 days interval at 30-60 cm depth are also presented in figure 2. The soil moisture content up to 30 cm did not show much variation among the treatments even though it varied among the month in accordance with the rainfall pattern. Interestingly the soil moisture content at 30-60 cm depth was considerably higher throughout the year in the Gypsum treated plots with higher in T_7.

The higher moisture content in subsoil especially during the dry month would have definitely resulted in higher yield. Here gypsum facilitated downward movement of water. Thus the moisture storage at subsurface layer is improved by gypsum treatment. At the end of October the moisture in subsoil depleted fast and storage of moisture was less in no gypsum soil than the gypsum treated soil. This may be attributed to higher moisture transmission of surface longer due to addition of gypsum.

The LGP based on climatological data could not be appropriate for the planning as the highest depletion of soil moisture in subsoil was observed at the end of October. The further increase of this moisture was attributed to slight irrigation given at 15 October 2009 to chickpea.

In conclusions, application of gypsum does not markedly affect the cumulative moisture use during and at different percent growing season of soybean and chickpea. However MUE of soybean significantly increased with increasing level of gypsum.

Higher MUE was found with T_6 (3 t gypsum ha^{-1}) but T_3 (1.5 t gypsum ha^{-1}) is enough to increase MUE of soybean significantly over no gypsum. Increasing level of gypsum also increase the MUE of chickpea.

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