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Assessment of Water Productivity of Soybean [*Glycine max* (L.) Merrill] based Cropping Systems under *Vertisols* in Malwa Plateau of Madhya Pradesh, India

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ABSTRACT

Background: In soybean growing areas, the agro-climatic conditions of mansoon season favours more to grow only soybean during *kharif* season even in assured irrigation water supply circumstances. But there is a magnificent opportunity to put back wheat during rabi season by adopting the diversification towards other crops which are having higher water productivity.

Methods: A field trial was conducted during rainy, *winter* and *late winter* seasons of the year 2015-16 and 2016-17 at the research farm of Krishi Vigyan Kendra, Dhar, M.P. to assess of water productivity of soybean [*Glycine max* (L.) Merrill] based cropping systems under *Vertisols* in Malwa Plateau of Madhya Pradesh, India. In 16 cropping sequences, soybean was sequenced with feasible *winter* crops *viz*. wheat, chick pea, garlic, onion, potato and garden pea with inclusion of garlic, onion in *late winter* and assessed in randomized block design with four replications.

Result: The maximum soybean equivalent yield (17731 kg/ha), net monetary returns (₹ 362170/ha), profitability (4.0), consumptive use (150.20 cm/ha) of water and productivity of water (367.35 kg/ha/cm) was recorded in crop sequence T_{15} - soybean (JS 93-05) - potato (Kufri jyoti) - onion (AFLR) while the minimum soybean equivalent yield (4279 kg/ha), consumptive use of water (60.09 cm/ha), water productivity (115.17 kg/ha/cm) and profitability (2.81) was noted in existing crop sequence *i.e.* T_3 - soybean (JS 95-60) - chickpea (JG-130) desi.

Key words: Consumptive use of water, Soybean based cropping sequences, Soybean equivalent yield, Water use efficiency.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is a major legume crop having two major quality characters *viz*. protein and oil. Soybean is known as 'miracle bean' rich in protein (40%) and moderate in oil (18-22%) and balanced amino acid and 20-30% extractable substance FAO (1982). It is widely grown in Madhya Pradesh, Maharashtra and Rajasthan and few pocket of Karnataka, Uttar Pradesh, Tamil Nadu and Andhra Pradesh as a sole or intercrop with pigeon pea, maize and cotton Singh *et al*. (2002). In India, it is grown on an area of about 11.33 million hectares, which is likely to produce more than 13.79 million tonnes with productivity 1217 kg/ha during the year 2019-20 (Anonymous, 2020). In order to that, Madhya Pradesh (5.60 million hectare), Maharashtra (4.04 million hectare) and Rajasthan (0.93 million hectare) constitute the major niche for the cultivation of soybean crop.

Water is a precious agro-resource of all living beings including crop. It works as solvent for nutrient elements, besides providing support for transportation of salts, sugars and solutes form one cell to another and one organ to another in the plants. It also plays a major role for photosynthesis and hydraulic processes in living plants like starch digestion. Water is a major constituent of physiologically active tissues and it is required for the maintenance of the cell turgidity. Water is also helpful in cell division, enlargement and ultimately essential in growth of plants. The availability of water as a resource for irrigation purpose in agriculture sector is now becoming most scarce.

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Hence, use of irrigation water in agriculture sector now drawing the attention that every drop of water should be utilizing efficiently. The indiscriminate use of irrigation water should be minimized because it is not only resulting into reduction of crop yields but also results as wastage of such costly agro-input, deteriorates the soil-properties, besides disturbances of agro-ecological balances. Looking the above facts in mind, the scientists belong to agriculture are developing such good agricultural practices, which are suitable for increasing water use efficiency in cropping systems.

It is generally come across that soybean-chickpea cropping system is being widely accepted by the cultivators through replacing soybean-wheat cropping system by virtue

of high market price of chickpea and less demand of irrigation water during growing period. Cultivation of chickpea in place of wheat is not gaining attraction of grower due to its quite low yielding ability. Water productivity is also known as water use efficiency which was estimated as rate of productivity of a crop or cropping system per unit area of land by using per unit quantity of given water as irrigation. Thus, water use efficiency of a particular cropping system mainly depends upon the productivity of various crop-components and consumptive use of water by them. At present, the whole world is facing water crises and seriously experiencing in all sectors of life including agriculture. Therefore, it is essential to evaluate the water productivity of various need based cropping sequences in central India.

MATERIALS AND METHODS

A field experiment was laid out during *rainy, winter* and *late winter* seasons of 2015-16 and 2016-17 at the research farm of Krishi Vigyan Kendra, Dhar, M.P. The soil of the experimental site was clay loam in texture, pH 7.60 with normal electrical conductivity (0.58 dS/m) and medium organic carbon content *i.e.* 0.59%. The experimental field was analysed and found values of major available nutrients *i.e.* N (236 kg/ha) low in available, P (11.60 kg/ha) medium in available and K (350 kg/ha) high in available contents. In these 16 cropping sequences, soybean was sequenced with feasible *winter* crops *viz*. wheat (*Triticum aestivum* and *Triticum durum* L.), chick pea (*Cicer arietinum* L.), garlic (*Allium sativum* L.*),* onion (*Allium cepa* L.), potato (*Solanum tuberosum* L.) and garden pea (*Pisum sativum* L.) with inclusion of garlic (*Allium sativum* L.*),* onion (*Allium cepa* L.) in *late winter* and tested in randomized block design with 4 replications.

Only soybean was grown during rainy season with two varieties *i.e.* JS 95-60 early duration (82-87 days) and JS 93-05 medium duration (90-95 days) under all cropping sequences. Different varieties as per their feasibility to accommodate the succeeding crop under present investigation were cultivated under different need based diversified cropping sequences. The variety used for winter crops was like wheat (HI-1544) aestivum, wheat (HI-8663) durum, chickpea (JG-130) *desi*, chickpea (RVKG-101) *kabuli*, Potato (Kufri jyoti), garden pea (Arkel) and garlic (G-282) and onion (AFLR) during *late winter*, respectively. Sowing of rainy, winter and *late* winter season crops were done on 21.06.15 and 26.06.16; 17.10.15 and 21.10.16 and 02.01.16 and 03.01.17 during two consecutive years, respectively. The recommended dose of N:P:K (kg/ha) for soybean 20:80:20, wheat 120:60:40, chick pea 20:60:20, garlic 100:50:50, onion 100:75:50, potato 120:50:100 and garden pea 20:60:20 was applied. On going through the above facts, water use efficiency of 16 soybean based cropping sequences including existing soybean - wheat and soybean - chickpea systems were evaluated under present investigation. The observations of experiment were recorded as per standard procedure. The experimental data was statistically analysed given by Gomez and Gomez (1984). The differences among treatments were calculated by using 'F' test and critically differences at 5% probability.

The methods of calculation of various cropping system indices with their references are as follows:

Soybean equivalent yield (SEY): The cropping sequences were evaluated in terms of soybean-equivalent yield as suggested by Yadav and Newaj (1990).

$$\text{Soybean equivalent yield (kg/ha)} = \frac{\text{Yield of a crop (kg/ha)} \times \text{Price of yield (₹/kg)}}{\text{Price of soybean yield (₹/kg)}}$$

Consumptive use of water

The consumptive use of water under different treatments was computed with the help of following equation as suggested by Dastane (1972).

$$Cu = \sum_{k=1}^{N} (E_p \times 0.8) + \sum_{i=1}^{N} \frac{M_{1i}-M_{2i}}{100} \times dbi \times Di + E_R$$

Where;

Cu = Consumptive use of water (mm).

E_p = Pan evaporation value (mm) from the USWB class A pan for the interval from the date of irrigation to the date of sampling after irrigation.

0.8 = A constant factor used to get E_t value by multiplying E_p value for a given period.

M_{1i} = Moisture per cent of i_{th} layer on the date of sampling after irrigation.

M_{2i} = Moisture per cent of i_{th}- layers on the date of sampling before irrigation.

db_i = Bulk density of i_{th} layer (mg/m^3).

D_i = Depth of 1st layer of soil (cm).

E_R = Effective rainfall (mm) if any during the period in consideration.

n = Number of soil layers.

N = Number of days from irrigation to sampling after irrigation.

Note: The values pertaining to irrigation varied depending on the crop and quantity of irrigation water used.

Water use efficiency

The water productivity is expressed in the productivity of a crop/crop-sequence per unit area with per unit quantity of water. It can also said to be water productivity (WUE). It was determined by using the formula as suggested by Dastane (1972).

$$\text{Water productivity(kg/ha/cm)} = \frac{\text{Soybean equivalent yields of the same crop sequence (kg/ha)}}{\text{Total consumptive use of water by all crop components in crop sequence (cm)}}$$

RESULTS AND DISCUSSION

Soybean equivalent yield (SEY)

The result showed that soybean equivalent yield of cropping system as a whole, soybean - potato - onion (T_{15}) registered

highest soybean equivalent yield (17731 kg/ha) among all crop sequences mainly due to top soybean equivalent yield of potato during *winter* along with considering good soybean equivalent yield of onion in *late winter*. The higher soybean equivalent yield in soybean - onion (T_{14}) and soybean - garlic (T_{13}) cropping sequence might be due to higher yield of onion in the sequence while minimum soybean equivalent yield was noted in existing soybean - chickpea (T_3) cropping sequence *i.e.* 4279 kg/ha (Table 1 and 2). This could be ascribed due to low yield realized from desi chickpea in the sequence. Similar results were reported by Billore *et al.* (2013), Gallani *et al.* (2013), Kumar and Kushwaha (2020), Narkhede *et al.* (2011) and Narolia *et al.* (2018).

Consumptive use of water

It is evident from both year data that the consumptive use of water was registered maximum (42.05 cm/ha) in T_{16} - soybean - garden pea - garlic and T_{15} - soybean - potato - onion

Table 1: Mean component yield (q/ha) in different seasons under various crop sequences.

Treatments	Grain/bulb/tuber yields (kg/ha)#					
	Rainy		*Winter*		*Late winter*	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1- Soybean - Wheat *aestivum*	1841	1960	4583	4930	-	-
T_2- Soybean - Wheat *durum*	1848	1987	4940	5305	-	-
T_3- Soybean - Chickpea *desi*	1881	2011	1580	1695	-	-
T_4- Soybean - Chickpea *Kabuli*	1905	1903	1723	1868	-	-
T_5- Soybean - Garlic	1937	2013	8343	8475	-	-
T_6- Soybean - Onion	1930	2022	21400	22618	-	-
T_7- Soybean - Potato - Onion	1958	2078	17968	19415	18556	19260
T_8- Soybean - Garden pea - Garlic	2002	2046	1160	1258	6840	7175
T_9- Soybean - Wheat *aestivum*	2043	2125	4788	4773	-	-
T_{10}- Soybean - Wheat *durum*	2017	2108	5123	5173	-	-
T_{11}- Soybean - Chickpea *desi*	1969	2144	1690	1730	-	-
T_{12}- Soybean - Chickpea *Kabuli*	1941	2135	1865	1971	-	-
T_{13}- Soybean - Garlic	2004	2233	8590	8680	-	-
T_{14}- Soybean - Onion	2031	2285	21780	2285	-	-
T_{15}- Soybean - Potato - Onion	1967	2290	18250	19830	19348	19785
T_{16}- Soybean - Garden pea - Garlic	2065	2248	1230	1325	7065	7360

Grain yields (q/ha)# = Grain yield in soybean, wheat, seed yield in chick pea, tuber in potato, bulb yield in onion and garlic.

Table 2: Soybean equivalent yield (kg/ha) under various cropping sequences.

Treatments	Soybean equivalent yield (kg/ha)								
	2015-16				2016-17				Pooled
	Rainy	*Winter*	*Late winter*	Total	*Rainy*	*Winter*	*Late winter*	Total	
T_1- Soybean - Wheat *aestivum*	1841	2914	-	4755	1960	3103	-	5063	4909
T_2- Soybean - Wheat *durum*	1848	3091	-	4939	1987	3308	-	5295	5117
T_3- Soybean - Chickpea *desi*	1881	2265	-	4146	2011	2400	-	4411	4279
T_4- Soybean - Chickpea *Kabuli*	1905	2768	-	4673	1903	2990	-	4893	4783
T_5- Soybean - Garlic	1937	6180	-	8117	2013	6277	-	8290	8204
T_6- Soybean - Onion	1930	7926	-	9856	2022	8377	-	10399	10128
T_7- Soybean - Potato - Onion	1958	7986	6873	16817	2078	8629	7133	17840	17329
T_8- Soybean - Garden pea - Garlic	2002	1719	5067	8788	2046	1863	5315	9224	9006
T_9- Soybean - Wheat *aestivum*	2043	3091	-	5134	2125	3308	-	5433	5284
T_{10}- Soybean - Wheat *durum*	2017	3260	-	5277	2108	3480	-	5588	5433
T_{11}- Soybean - Chickpea *desi*	1969	2350	-	4319	2144	2500	-	4644	4482
T_{12}- Soybean - Chickpea *Kabuli*	1941	2850	-	4791	2135	3050	-	5185	4988
T_{13}- Soybean - Garlic	2004	6250	-	8254	2233	6350	-	8583	8419
T_{14}- Soybean - Onion	2031	8150	-	10181	2285	8520	-	10805	10493
T_{15}- Soybean - Potato - Onion	1967	8082	7166	17215	2290	8629	7328	18247	17731
T_{16}- Soybean - Garden pea - Garlic	2065	1720	5233	9018	2248	1970	5452	9670	9344
SEm±	52	282	66	141	58	150	68	175	112
CD (P=0.05)	147	807	190	404	166	429	195	500	315

Table 3: Mean consumptive water use (cm/ha) of various cropping components under various cropping sequences.

Treatments	Mean consumptive water use (cm/ha)											
	Rainy			*Winter*			*Late winter*			Total		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Pooled
T_1- Soybean - Wheat *aestivum*	37.51	38.20	37.86	47.5	44.5	46.00	-	-	-	85.02	82.70	83.86
T_2- Soybean - Wheat *durum*	38.60	37.90	38.25	48.8	49.6	49.20	-	-	-	87.40	87.50	87.45
T_3- Soybean - Chickpea *desi*	37.32	38.60	37.96	22.3	21.97	22.14	-	-	-	59.62	60.57	60.09
T_4- Soybean - Chickpea *Kabuli*	39.40	37.50	38.45	21.8	22.48	22.14	-	-	-	61.20	59.98	60.59
T_5- Soybean - Garlic	36.90	37.60	37.25	49.6	48.5	49.05	-	-	-	86.50	86.10	86.30
T_6- Soybean - Onion	37.00	38.50	37.75	56.8	57.9	57.35	-	-	-	93.80	96.40	95.10
T_7- Soybean - Potato - Onion	35.90	36.80	36.35	44.6	41.2	42.90	58.90	60.20	59.55	139.40	138.20	138.80
T_8- Soybean - Garden pea - Garlic	35.80	36.50	36.15	35.2	36.3	35.75	50.20	51.50	50.85	121.20	124.30	122.75
T_9- Soybean - Wheat *aestivum*	39.40	29.20	34.30	45.9	46.3	46.10	-	-	-	85.30	75.50	80.40
T_{10}- Soybean - Wheat *durum*	38.90	38.50	38.70	49.2	48.9	49.05	-	-	-	88.10	87.40	87.75
T_{11}- Soybean - Chickpea *desi*	39.10	39.20	39.15	21.8	22.3	22.05	-	-	-	60.90	61.70	61.30
T_{12}- Soybean - Chickpea *Kabuli*	37.80	37.90	37.85	22.7	22.9	22.80	-	-	-	60.50	60.80	60.65
T_{13}- Soybean - Garlic	39.20	39.50	39.35	48.8	49.8	49.30	-	-	-	88.00	89.30	88.65
T_{14}- Soybean - Onion	39.40	38.90	39.15	57.9	58.6	58.25	-	-	-	97.30	97.50	97.40
T_{15}- Soybean - Potato - Onion	40.20	42.30	41.25	47.8	45.9	46.85	62.50	61.70	62.10	150.50	149.90	150.20
T_{16}- Soybean - Garden pea - Garlic	41.60	42.50	42.05	36.4	37.8	37.10	55.30	56.80	56.05	133.30	137.10	135.20
SEm±	-	-	-	-	-	-	-	-	-	0.69	0.68	0.49
CD (P=0.05)	-	-	-	-	-	-	-	-	-	1.98	1.94	1.36

Table 4: Water productivity (kg/ha/cm) of different cropping components under various crop sequences.

Treatments	*Rainy*			*Winter*			*Late winter*			Total		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Pooled
T_1- Soybean - Wheat *aestivum*	49.08	51.31	50.19	61.35	69.73	65.54	-	-	-	110.43	121.04	115.74
T_2- Soybean - Wheat *durum*	47.88	52.43	50.15	63.34	66.69	65.02	-	-	-	111.22	119.12	115.17
T_3- Soybean - Chickpea *desi*	50.40	52.10	51.25	101.57	109.24	105.40	-	-	-	151.97	161.34	156.66
T_4- Soybean - Chickpea *Kabuli*	48.35	50.75	49.55	126.97	133.01	129.99	-	-	-	175.32	183.75	179.54
T_5- Soybean - Garlic	52.49	53.54	53.02	124.60	129.42	127.01	-	-	-	177.09	182.96	180.03
T_6- Soybean - Onion	52.16	52.52	52.34	139.54	144.68	142.11	-	-	-	191.70	197.20	194.45
T_7- Soybean - Potato - Onion	54.54	56.47	55.50	179.06	209.44	194.25	116.69	118.49	117.59	332.67	360.90	346.79
T_8- Soybean - Garden pea - Garlic	55.92	56.05	55.99	48.84	51.32	50.08	100.94	103.20	102.07	191.52	201.00	196.26
T_9- Soybean - Wheat *aestivum*	51.85	52.77	52.31	67.34	71.45	69.39	-	-	-	119.19	124.22	121.71
T_{10}- Soybean - Wheat *durum*	51.85	54.75	53.30	66.26	71.17	68.71	-	-	-	118.11	125.92	122.02
T_{11}- Soybean - Chickpea *desi*	50.36	54.69	52.53	107.80	112.11	109.95	-	-	-	158.16	166.80	162.48
T_{12}- Soybean - Chickpea *Kabuli*	51.35	56.33	53.84	125.55	133.19	129.37	-	-	-	176.90	189.52	183.21
T_{13}- Soybean - Garlic	51.12	56.53	53.83	128.07	127.51	127.79	-	-	-	179.20	184.04	181.62
T_{14}- Soybean - Onion	51.55	58.74	55.14	140.76	145.39	143.08	-	-	-	192.31	204.13	198.22
T_{15}- Soybean - Potato - Onion	48.93	54.14	51.53	169.08	188.00	178.54	114.66	118.77	116.71	350.29	384.40	367.35
T_{16}- Soybean - Garden pea - Garlic	49.64	52.89	51.27	47.25	52.12	49.68	94.63	95.99	95.31	205.69	210.58	208.14
SEm±										2.01	4.18	2.32
CD (P=0.05)										5.75	11.95	6.50

Table 5: Economics of soybean based different crop- sequences.

Crop sequences	Cost of cultivation	Net monetary return (₹ /ha)			B:C ratio		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1- Soybean - Wheat *aestivum*	45100	86974	94009	90492	2.93	3.05	2.99
T_2- Soybean - Wheat *durum*	45200	91671	99763	95717	3.03	3.19	3.11
T_3- Soybean - Chickpea *desi*	41500	73053	78594	75824	2.76	2.86	2.81
T_4- Soybean - Chickpea *Kabuli*	42000	86128	93551	89840	3.05	3.19	3.12
T_5- Soybean - Garlic	70700	149553	154578	152066	3.12	3.18	3.15
T_6- Soybean - Onion	75200	192203	206513	199358	3.56	3.72	3.64
T_7- Soybean - Potato - Onion	120900	333926	360593	347260	3.76	3.98	3.87
T_8- Soybean - Garden pea - Garlic	79900	156703	169313	163008	2.96	3.10	3.03
T_9- Soybean - Wheat *aestivum*	45100	95337	102629	98983	3.11	3.24	3.18
T_{10}- Soybean - Wheat *durum*	45300	99934	107858	103896	3.21	3.34	3.27
T_{11}- Soybean - Chickpea *desi*	41500	81416	87114	84265	2.96	3.05	3.01
T_{12}- Soybean - Chickpea *Kabuli*	42000	94491	102521	98506	3.25	3.39	3.32
T_{13}- Soybean - Garlic	70700	157916	162673	160295	3.23	3.27	3.25
T_{14}- Soybean - Onion	75200	200566	214558	207562	3.67	3.81	3.74
T_{15}- Soybean - Potato - Onion	120700	350151	374188	362170	3.90	4.08	4.00
T_{16}- Soybean - Garden pea - Garlic	80000	169466	178858	174162	3.12	3.15	3.13
SEm±	230	1653	2951	1691	0.04	0.04	0.03
CD (P=0.05)	658	4724	8434	4736	0.10	0.13	0.08

Value of soybean, wheat, chick pea (desi), chick pea (kabuli), garlic, onion, potato, garden pea is ₹ 2700, 1500, 3500, 4000, 2000, 1000, 1200, 4000 respectively and value of straw of soybean, wheat and chick pea was ₹ 180, ₹ 150 and ₹ 250 respectively. (Values on the basis of market price during 2016-17).

41.25 cm/ha respectively during rainy season. In *winter* season, onion grown after soybean (T_{14}) recorded maximum consumptive use of water (58.25 cm/ha). In *late winter*, onion had registered maximum consumptive use of water (62.10 cm/ha). While considering the consumptive water use of an individual cropping system as a whole, soybean - potato - onion (T_{15}) cropping sequence recorded maximum consumptive water use (150.20 cm/ha) closely followed by T_{16} - soybean - garden pea - garlic (135.20 cm/ha) respectively over existing soybean - chickpea (T_3) cropping system (Table 3). Similar finding was reported by Billore *et al.* (2013), Kumar and Kushwaha (2020) and Narolia *et al.* (2018).

Water use efficiency

While considering, the water use efficiency of different cropping sequences as a whole, soybean - potato – onion (T_{15}) registered maximum water use efficiency (367.35 kg/ha/cm) as compared to existing T_1 - soybean - wheat (115.74 kg/ha/cm) cropping sequence (Table 4). Inclusion of garlic and onion during late *winter* in different soybean based cropping systems helped to achieve the considerable water use efficiency of different diversified intensive cropping system. Similar finding was reported by Billore *et al.* (2013), Kumar and Kushwaha (2020) and Narolia *et al.* (2018).

Economics (Profitability)

Results revealed that soybean - potato - onion (T_{15}) sequence needed maximum investment (₹ 1,20,900) for growing every component of crops because of highest cropping intensity (300%) than the prevailing cropping sequences *viz.* soybean-wheat (₹ 45,100/ha) and soybean - chickpea (₹ 41,500/ha) systems. Soybean - potato - onion (T_{15}) system registered maximum net monetary returns of ₹ 3,62,170/ha and profitability (4.0) among all crop sequences mainly due to high production potential of entire cropping system (Table 5) than existing cropping sequences *viz.* T_1 - soybean - wheat (2.99) and T_3- Soybean - Chickpea (2.81). Similar results were reported by Billore *et al.* (2013), Gallani *et al.* (2013), Kumar and Kushwaha (2020), Narkhede *et al.* (2011) and Narolia *et al.* (2018).

CONCLUSION

It is concluded that the maximum soybean equivalent yield (17731 kg/ha), net monetary returns of ₹ 3,62,170/ha, profitability (4.0), water consumptive use (150.20 cm/ha) and water use efficiency (367.35 kg/ha/cm) was recorded in crop sequence soybean - potato - onion (T_{15}) among all crop sequences mainly due to high production potential of entire cropping system whereas, the minimum soybean-equivalent yield (4279 kg/ha), consumptive use of water (60.09 cm/ha) and water use efficiency (115.17 kg/ha/cm) was noted in existing soybean - chickpea (T_3). The results revealed that there is ample scope to intensify the existing cropping sequence with inclusion of onion and garlic during *late winter*.

Based upon above facts, the farmers have choice to select any suitable cropping system depending on their investment capacity.

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