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Nanotechnological approaches to study the effect of silver nanoparticles on yield, quality and shelf life of onion

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Abstract

An experiment was conducted to understand the effects silver nanoparticles (AgNPs), on yield, quality and shelf life of onion, varieties Arka Pragati. AgNPs of less then100 nm size in five different concentrations, viz. 0, 25, 50, 75 and 100 ppm were used as a treatment. Result indicates that impact of AgNPs in different parameters was concentration dependent. Higher concentration of AgNPs gives batter result then low concentration. Maximum yield was recorded in 100 ppm (38.10 t/ha) compare to control (33.33t/ha). Maximum equatorial diameter, polar diameter, ten bulb weight, number of ring was observed in T1 (100ppm) but no significant difference was observed among all the treatment for TSS and bulb dry weight. A noticeable result was also recorded in shelf life also. Rotting percentage (%) and Black mould incident was reduced considerable in T4 however no significant difference was observed in PLW and TSS during storage.

Keywords: Silver nanoparticles (AgNPs), onion, Arka Pragati, yield, quality, shelf life

Introduction

Yield and quality of food can be improved by modern technologies which may be able to meet ever increasing world food demand (Wheeler, 2005). Nanotechnology seems to have potential for addressing the problem of food security (Anonymous, 2009) and may bring changes in crop production. Nanoparticles (NPs) have unique physiochemical properties such as high reactivity, high surface area, particle morphology, tunable pore size. Many NPs have a plant growth promoting effects, which have enormous applications in agriculture (Farooqui *et al.* 2016) [7]. *Vigna radiata* exhibited increase in biomass on application of AgNPs (Mishra, *et.al* 2014) [8]. It was observed that seedling growth of the *S. bicolor* exposed to AgNPs of 40 mg/l was increased by 47% (Woo-Mi *et al.*, 2012) [9]. Onion (*Allium cepa* L.) is being cultivated for food, medicine and as a major vegetable crop since prehistoric time, consumed regularly by the entire world. India is second largest in area and production in the world after china and third largest exporter of onion after, the Netherlands and Spain. Productivity of onion in India in low then the many counties and this low productivity is due to verity, biotic, abiotic stress and the type of verity. Many techniques have been developed to overcome such problems but all has its own limitation. Hence the present investigation was made to study the effect of AgNPs on yield, quality and shelf life of onion.

Materials and Methods

Onion (*Arka Pragati*) seedlings of 45 days old was planted in RBD design with fore replication in the main field at a spacing of 10×15 cm. Standard package of practices was followed for crop production. Four *different concentration of* AgNPs *i.e.* 25ppm 50ppm 75ppm and 100ppm were applied on onion plant as an aerial spray.1st spray was given on 45 days and another two spay on 15 days interval. Simultaneously a control was also maintained. All the disease and insect pest was controlled by the agrochemicals as needed. For physiological parameter four observations was recorded in fortnight interval starting from 45 DAP. The yield and quality parameters were recorded after harvesting of the crop. Further Harvested bulb was stored in room temperature accordingly treatment and replication for the postharvest study. No other additional treatment was given to the bulb. The observation was recorded in every 15 days for 90 days of storage.

Observations were recorded on five randomly selected plants from each entry in each replication for. The leaf length was measured from the base of the leaf to the terminal most part of the leaf and expressed in centimetre. Plant height was measured from neck of the bulb to the tip of the longest leaf and expressed in centimetre.

Number of fully grown green functional leaves was counted on selected plants and the average number of leaves per plant worked out. Diameter of the leaf was measured by the Vernier callipers. The weight of both marketable and unmarketable bulbs was added to get the total yield. Ten randomly selected bulbs from each treatment were weighed and their weight was recorded. The neck thickness was measured with the help of Vernier callipers just above the top of the bulb and presented in centimetre. The bulb diameter at the maximum thickness of the bulb across the polar length was measured with the help of Vernier callipers. The length between two polar ends of bulbs recorded with the help of Vernier callipers and mean diameter was calculated. The number of complete fleshy rings encircling the growing centre were recorded, when the bulbs were cut across the equatorial region. The total soluble solids were recorded with the help of hand refractometer in bulbs and the average was calculated. 100 g of fresh sample of the bulbs was dried in the oven at 65°C for three days to get dry weight percentage of the bulb. A composite sample from ten bulbs for each line was taken for this trait. Marketable bulb yield (t/ha), Unmarketable bulb yield (t/ha), Rotted bulb Weight (t/ha), Bolted bulb Weight (%) and Days to maturity (days) was also recorded.
Fore parameter was chosen to study the shelf life of bulb. To get the Physiological loss in weight (%), the weight of the stored bulbs was recorded on 15, 30, 45, 60, 75 and 90 days after storage using an electronic balance. The cumulative loss in weight of bulbs was calculated and expressed as per cent physiological loss in weight using the formula given below.

$$PLW\ (\%) = \frac{\text{P – P1 or P2 or P3 or P4 or P5 or P6}}{P} \times 100$$

Where,
P = initial weight
P1 = weight after 15 days
P2 = weight after 30 days
P3 = weight after 45 days
P4 = weight after 60 days
P5 = weight after 75 days
P6 = weight after 90 days

Total soluble solids (TSS, %) of the selected bulb was recorded by using a Hand Refractometer (Erma Japan) 0 to 32 per cent range. The values were expressed as per cent total soluble solids of the bulbs (Anon., 1984). The rotted bulbs were identified manually form each treatment and replication at the end of 15, 30, 45, 60, 75 and 90 DAS then the weight of the rotted bulbs was recorded and the rotting percentage was calculated by using the formula.

$$\text{Rotting percentage} = \frac{Weight\ of\ the\ rotted\ bulbs}{Initial\ weight\ of\ the\ bulbs} \times 100$$

The black mould incidence, a major storage disease caused by *Aspergillus niger* Van Trieghen was recorded at 15 days interval till 90 days of storage.

Result and Discussion

Result clearly demonstrates that areal spray of silver nanoparticle affect the leaf length. Different concentration has different degree of response on plant. On 2nd observation (60DAP), control (63.20 cm), T1 (63.80 cm), and T2 (64.10 cm) was at par. On the other sight T3 (67.40 cm) and T4 (68.08 cm) were at par but there were significantly superior over all other treatment (table 1). However on 4th (90 DAP) and final observation T4 (85.78 cm) performed as a best treatment for this parameter followed by T3 (81.90). No significant difference was observed between control (73.90 cm) and T1 (74.90 cm) however all other treatments were significantly differ from each other. Similar kind of response was observed for plant height. Observation regarding the plant height is presented in Table 4. No significant differences were observed on 45 DAP but nanoperticle was started showing its effect after fast spray onwards only. Maximum plant height was observed in T4 (71.08 cm) followed by T3 (70.95 cm) at 60 DAP whereas minimum was observed in control (66.16cm) followed by T2 (67.15 cm). Although control, T1 and T2 was at par on the other site T3 and T4 was at par (table 1). Similar king of treads was observed at 75 DAP observation but on 90 DAP there was no significant differences among control (82.60 cm) and T1 (84.20 cm) but T2 (87.47 cm), T3 (95.45 cm) and T4 (100.00 cm) was significantly differ from each other. Maximum plant height was observed in T4 (100.00 cm). Observation of Seif *et al.* (2011) [1] supports our finding as he reported that plant height of Borago was increase on the application of AgNPs. Maximum number of leaf was observed in T4 (15.98) (table 2) which is much higher than control (11.88) which is a good indication because more number of leaf leads to more number of ring as a result the bulb size increases. It has been observed that AgNPs had a clear positive impact on leaf diameter. Higher the concentration more the leaf diameter was observed. Maximum leaf diameter was observed in T4 on 90 days old plant (16.48mm) however T3 (75ppm) was at par with T4 (table 2). In the same observation T1 (14.13 mm) was at par with control (13.85 mm) and T2 (14.73 mm) was at par with T1. On second observation (60 DAP) all the treatment was significantly differ from each other but a similar trends like 4th observation (90 DAP) was observed on 3rd observation (75 DAP). In wheat Muhammad, *et al.* (2017) observed a similar result in which AgNPs remarkably increase the leaf area of Wheat. Root length (cm) and Number of root of onion plant was positively influenced by AgNPs treatment. The response increased with the increasing concentration gradient of the treatment. The maxima root length was observed in T4 (24.90 cm) followed by T3 (23.80cm) however there were at par (table 3). Control had a length of 19.50 cm followed by T1 (20.80 cm) and T2 (22. 10cm). T1, T2 and control were significantly differing from each other. Maximum root number was noticed in T4 with 114 number of root followed by T3 (105.30) on the other side minimum number of root was observed in control (83.75) followed by T1 (93.35) and T2 (99.85). T4 had significantly higher number of root then all other treatments except T3. In a finding Salama (2012) [2] and Sharma *et al.* (2012) reported that AgNPs increased plant growth attributes such as root and shoot length and leaf area in *B. juncea*, *P. vulgaris and Z. mays*.
Yield is one of the most important parameter to consider. Experimental data regarding the total yield is presented in Table 4 and it suggests that the AgNPs has a positive effect on bulb yield but concentration dependent. Higher concentration (100ppm) gives a higher bulb yield than the low concentration. Maximum bulb yield was recorded in T4 (38.10 t/ha) followed by T3 (35.53t/ha) and T2 (34.03t/ha) on the other hand minimum yield was recorded in T1 (32.08t/ha) followed by control (33.33t/ha). Rezzaq *et al.*, 2016 [3] reported a similar finding in wheat and he observed a remarkable increase in grain yield in wheat when AgNPs was applied. Highest total marketable yield was recorded in T4 (37.54 t/ha) followed by T3 (34.71 t/ha) and T2 (33.09 t/ha) and there were significantly differ from each other. Lowest total marketable yield was recorded in T1 (31.27) followed by control (32.57 t/ha) and they were at par (table 4). Whereas no

significant differences were observed for unmarketable yield among the treatments but the data ranges from 0.66 t/ha (T4) to 0.93 t/ha. AgNPs also have the potential to boost the 10 bulb weight of onion (Table 4). The ten bulb weight was ranging from 832.00g to 1085.88g. T1 (830.50 g) and T2 (850.50 g) was at par with each other and also with control (832.00 g) however, highest tend bulb weight was recorded in T4 (1085.88g) followed by T3 (1028.25 g) though they were at par of each other. An unusual Result was observed in case of bolting percentage (table 3.). Maximum bolting % was observed in T2 (2.53%) followed by T1 (2.03%). Minimum bolting % was observed in control (1.30%) followed by T3 (1.43%) and T4 (1.85%). A dedicated systematic investication must be carry out to understand such phenomenon. Equatorial diameter and Polar diameter are the important parameter to understand the size and the shape of the bulb. Experimental result clearly indicates the bulb size of the treated plant was increased considerably. A gradual increase in equatorial diameter was observed along the increasing concentration on AgNPs. Maximum equatorial diameter was observed in T4 counting 7.54 cm followed by T3 (6.63 cm) and T2 (6.03 cm), they were significantly differ from each ether (table 5). Minimum equatorial diameter was observed in control (5.65 cm) followed by T1 (5.83cm) and they were at par. Treatment T1 and T2 were also at par in this parameter (Table 9). Maximum polar diameter was observed in T4 (6.81cm) followed by T3 (6.10 cm) and T2 (5.63 cm), they were significantly differ from each ether however Minimum polar diameter was observed in control (5.15 cm) followed by T1 (5.25cm) and they were at par (Table 5). Among all the treatment T4 (12.03) had the highest and significantly higher number of ring comparer to control (10.05) however T4, T3 (11.68) and control, T1 (10.18) were at pre but T2 (10.80) was significantly differ from control, T1, T3 and T4 (Table 5). Morozowska *et al.* (2009) [4] mentioned that for each leaf there will be a ring of onion formed. In our study also observed that T4 produced maximum number of leaf. It has been explained in a report that AgNPs stimulate shoot growth by jamming ethylene signalling which is a shoot growth inhibitor (Rezvani *et al.* 2012; Syu *et al*. 2014) [6, 5], similar kind of mechanism might have involved in this case also increasing the number of leaf per plant which leads to increase in number of ring per bulb. Statistical analysis (Table 5) clearly indicates that AgNPs does not affect the TSS of the bulb however highest TSS was observed in T1 (12.50^0 Brix) followed by T4 ($12.43\ ^0$ Brix). Similar response was observed in bulb dry weight and Dry weight of leaf also. Data anticipated in Table 9 clearly represent that silver nanoparticle had a positive effect on the neck thickness of the bulb. In both the year neck thickness was increased considerably with the increased concentration of AgNPs however poll analysis advocate that minimum neck thickness was observed in controlled (0.99 cm) followed by T1 (1.04 cm) and T3 (1.17 cm) on the other side highest neck thickness was on T4 (1.48) followed by T3 (1.37 cm). T4 was significantly higher Neck thickness than other treatment other then T3 but control; T1 and T2 were at par. T3 and T2 were also at par. Interesting finding was observed in Days to maturity. Data presented in Table 10 indicates that AgNPs has the capability to delay the maturity of onion crop up to 13 days depending upon the concentration of the solution. T4 and T3 taken maximum day (135 days) to mature compare to control 121 days however T1 taken 124 days and T2 taken 126 days to mature (table 3).

Four parameters were considered for study of self-life. Perusals of data given in Table 6 reveal that there were no significant differences among the treatment in all the observations for PLW. But the bulbs showed a gradual increase in the physiological loss in weight (%) (PLW) with the storage period in all the treatments. It was observed that mean of each observations was greatly differ from each other ranges from 5.52 cm to 19.83%. Similarly no significant differences among the treatments, in any of the observations was recorded for TSS However, Irrespective of the mean TSS content of bulbs increased gradually from 12.90 per cent at 15.00 DAS to 16.03 per cent at 90 DAS (table 7)**.** The gradual increase in the TSS could be because of the moisture loss from the bulb also for the conversion of insoluble sugars into soluble forms and least utilization of organic acids (Singh and Dhankhar, 1992, Misra and Pandey, 1979 and Aoyagi *et al*. 1997). The results on rotting percentage are presented in Table 8 which indicates that the significant deviation in respect to rotting percentage of onion bulbs due to different treatments. There was no rotting (%) up to 15 days in all the treatments. However, at 30 Day onwards rotting was observed and gradually increased for all the treatment as the time progressed. The cumulative mean rotting % was observed 2.44% at 30 days which has increased 11.80%. There were no significant differences among the treatment at 15 days and 60 day of observation however a significant difference was observed at 30 days, 45 days, 75days and 90 day of observation. For all the observation T4 was recorded as a best pre harvest treatment with minimum rotting %. At 75 day of observation T4 (7.19%) was significantly superior over all other treatments except T3 (8.18%). Similarly 90 day of observation T4 (9.61%) was significantly superior over all other treatments except T3 (10.23%). Irrespective of treatments the black mould ((*Aspergillus niger*) (%) increased progressively from 3.00% at 30 days to 11.60% at 90 days (table 9). No infection was observed till 15 days of storage. There were no significant differences among the treatment at 15 days, 30 days and 60 days but significant differences were observed at 45 days, 75 days and 90 days. It was observed in final observation that T4 (8.50%) treated bulbs were less infected by *Aspergillus niger* followed by T3 (9.50%) though they were at par but T4 were significantly superior then other treatment. In all the observation (15days, 30 days, 45 days, 60 days, 75 days and 90 days) T4 was recorded with minimum infection *i.e.* 0.00%, 2.00%, 3.00%, 6.50%, 7.50% and 8.50% respectively. AL-Othman *et al.* (2014) [11] in a study articulated that *Aspergillu. flavus* isolates were inhibited to various extents by different concentrations of silver nanoparticles.

Table 1: leaf length (cm) and Plant height (cm) of onion plant at different growth stage.

Treatment	Plant height				Leaf length			
	45 DAP	60 DAP	75 DAP	90 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Control	38.35	66.16^b	76.80^b	82.60^d	38.35	63.20^b	69.85^d	73.90^d
T1	38.03	67.15^b	78.83^b	84.20^d	38.02	63.80^b	71.70^c	74.90^d
T2	37.10	67.58^b	80.82^b	87.47^c	37.10	64.10^b	72.30^c	76.20^c
T3	38.85	70.95^a	86.25^a	95.45^b	38.85	67.40^a	76.70^b	81.90^b
T4	38.25	71.80^a	90.45^a	100.00^a	38.25	68.08^a	79.98^a	85.78^a
CD @5%	NS	2.45	4.68	3.65	NS	1.19	1.54	1.19
SEm±	NS	0.79	1.52	0.84	NS	0.38	0.50	0.38

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 2: Number leaves and Diameter of leaves of onion plant at different growth stage.

Treatment	Number of leaves				Diameter of leaves(mm)			
	45 DAP	60 DAP	75 DAP	90 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Control	7.82	9.76^{c}	10.55^{c}	11.88d	7.92	12.85^{e}	13.25^{c}	13.85^{c}
T1	7.15	9.55^{bc}	11.15^{c}	12.85cd	7.62	13.73^{d}	13.93^{bc}	14.13b^{c}
T2	6.62	10.06^{b}	12.83^{b}	13.51c	7.82	14.33^{c}	14.43^{b}	14.73^{b}
T3	7.43	11.63^{a}	14.32^{a}	15.88a	7.95	15.48^{b}	15.68^{a}	15.88^{a}
T4	6.64	11.80^{a}	14.74^{a}	15.98a	7.49	16.08^{a}	16.24^{a}	16.48^{a}
CD @5%	NS	1.57	0.95	1.06	NS	0.51	0.69	0.62
SEm±	NS	0.52	0.17	0.31	NS	0.17	0.23	0.20

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 3: Bulb dry weight, Dry weight of leaf, Root length (cm), Number of root (cm) and Days to maturity of AgNPs treated onion.

Treatment	Bulb dry weight (%)	Dry weight of leaf (%)	Root length (cm)	Number of root (cm)	Bolting %	Days to maturity
Control	12.10	10.17	19.50^{d}	83.75^{d}	1.30^{db}	121.00
T1	12.30	9.89	20.80^{c}	93.35c^{d}	2.03^{a}	124.00
T2	12.95	10.64	22.10^{b}	99.85b^{c}	2.53^{a}	126.00
T3	12.80	10.86	23.80^{a}	105.30^{ab}	1.43^{b}	135.00
T4	13.43	10.97	24.90^{a}	114.00^{a}	1.85^{b}	135.00
CD @5%	NA	NA	1.20	9.65	0.51	-
SEm±	NA	NA	0.39	3.13	0.17	-

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 4: Yield parameter of AgNPs treated onion.

Treatment	Total yield	Total marketable yield	Total Unmarketable yield	Ten bulb weight
Control	33.33^{d}	32.54^{d}	0.79	832.00^{b}
T1	32.08^{cd}	31.27^{cd}	0.81	830.50^{b}
T2	34.03^{c}	33.09^{c}	0.93	850.50^{b}
T3	35.53^{b}	34.71^{b}	0.82	1060.50^{a}
T4	38.10^{a}	37.45^{a}	0.66	1138.00^{a}
CD @5%	1.49	1.47	NS	81.32
SEm±	0.49	0.48	NS	23.39

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 5: quality parameter of AgNPs treated onion.

Treatment	Equatorial diameter (cm)	Polar diameter (cm)	Number of ring	TSS (^{0} Brix):	Neck thickness (cm)
Control	5. 65^{cd}	5. 15^{d}	10.05^{c}	12.33	0.99^{b}
T1	5. 83^{c}	5. 25^{d}	10.18^{c}	12.50	1.04^{b}
T2	6.03^{c}	5.63^{c}	10.80^{b}	12.20	1.17^{ab}
T3	6.63^{b}	6.10^{b}	11.68^{a}	12.40	1.37^{a}
T4	7.54^{a}	6.81^{a}	12.03^{a}	12.43	1.48^{a}
CD @5%	0.25	0.33	0.39	NA	0.32
SEm±	0.08	0.11	10.3	NA	0.10

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 6: Physiological loss of weight (PLW) of AgNPs treated onion.

Treatment	Physiological loss of weight (%)					
	15 days	30 days	45 days	60 days	75 days	90 days
Control	5.48	7.78	11.48	13.14	16.78	19.98
T1	5.65	7.68	11.08	13.48	17.01	20.03
T2	5.58	7.75	10.85	13.05	16.73	19.93
T3	5.35	7.38	9.95	12.60	16.48	19.50
T4	5.55	7.65	10.73	12.40	16.30	19.73
Mean	5.52	7.65	10.82	12.93	16.66	19.83
CD @5%	NS	NA	NA	NA	NA	NA
SEm±	NS	NA	NA	NA	NA	NA

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 7: Changes on TSS during storage of AgNPs treated onion

Treatment	TSS (^{0}Brix)						
	0 days	15 days	30 days	45 days	60 days	75 days	90 days
Control	12.33	12.95	13.65	14.50	14.73	15.48	16.03
T1	12.50	12.88	13.48	14.35	14.95	15.75	16.05
T2	12.20	12.75	13.40	14.23	14.83	15.73	16.20
T3	12.40	12.95	13.88	14.75	15.10	15.85	16.40
T4	12.43	12.98	13.38	14.25	14.80	15.50	16.03
Mean	12.37	12.90	13.56	14.42	14.88	15.66	16.14
CD @5%	NS	NS	NS	NS	NS	NS	NS
SEm±	NS	NS	NA	NA	NA	NA	NA

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 8: Rotting percentage (%) during storage of AgNPs treated onion

Treatment	Rotting percentage (%)					
	15 days	**30 days**	**45 days**	**60 days**	**75 days**	**90 days**
Control	0.0	3.18a	5.89a	8.42	11.23a	12.87a
T1	0.0	2.93ab	5.90a	8.03	11.70a	14.40a
T2	0.0	2.31bc	5.14ab	7.08	10.49ab	12.45ab
T3	0.0	1.92c	4.27bc	6.45	8.10bc	10.11bc
T4	0.0	1.85c	3.08c	6.11	7.19c	9.16c
Mean	0.00	2.44	4.86	7.22	9.74	11.80
CD @5%	NS	0.84	1.43	NS	2.55	2.51
SEm±	NS	0.27	0.46	NS	0.82	0.81

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

Table 9: Black mould incident of AgNPs treated onion

Treatment	Black mould incident (%)					
	15 days	**30 days**	**45 days**	**60 days**	**75 days**	**90 days**
Control	0.0	4.00	6.00ab	10.00	13.00	14.50a
T1	0.0	4.00	6.50a	10.00	12.50	13.00a
T2	0.0	3.00	6.00ab	9.00	12.00	12.50ab
T3	0.0	2.00	3.50bc	6.50	8.00	9.50bc
T4	0.0	2.00	3.00c	6.50	7.50	8.50c
Mean	0.00	3.00	5.00	8.40	10.60	11.60
CD @5%	NS	NA	2.5	NA	2.08	3.08
SEm±	NS	NA	0.83	NA	0.68	1.02

Control = 0 ppm AgNPs; T1=25 ppm AgNPs; T2=50 ppm AgNPs; T3=75 ppm AgNPs; T4=100 ppm AgNPs

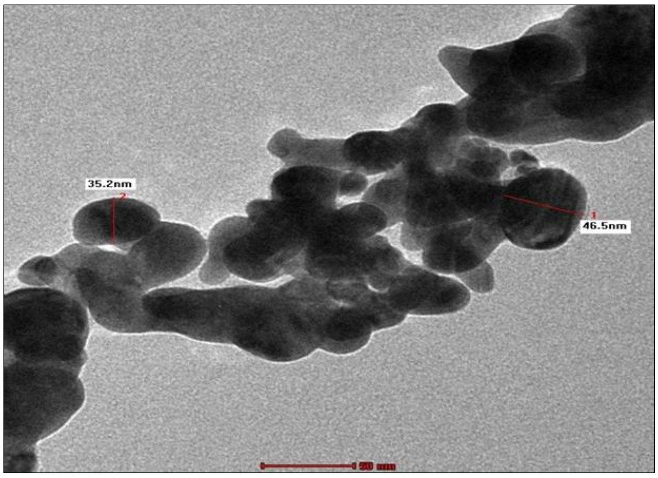

Fig 1: Image of silver nanoparticles size by Transition Electron Microscope (TEM)

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