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REGULAR ARTICLE

Growth and development of *Jatropha curcas* seedlings using Terracotem soil conditioners under different irrigation levels

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ABSTRACT

Jatropha curcas L., a multipurpose plant originated from Central and South America, is receiving increase interest as a biofuel feedstock. Desirable characteristics such as drought tolerance and the ability to grow in marginal lands with low inputs, triggered the development of several projects around the World, not always successful. In fact, despite this hype, *J. curcas* remains a new crop for which the agronomic requirements are not yet fully understood. For example water requirements of the crop are subject to debate, and in the initial growth stages a considerable amount of water is necessary. We performed a glasshouse experiment to study the influence of water levels and the use of soil conditioners in the growth and development of *J. curcas* seedlings in the nursery. Results show a positive influence of water level on most of the growth and development parameters studied. The use of soil conditioners also did contributed to a better plant growth. A combination of moderate supply of water and soil conditioners could allow water saving of about 50% in the nursery.

Keywords: Biofuel crop; Physic nut; Water saving; Soil conditioners

INTRODUCTION

Jatropha curcas L. is a perennial shrub or tree belonging to the family Euphorbiaceae which in the last decades has received considerable attention from researchers and several stakeholders due to, among many uses, its potential as a feedstock for renewable biofuel production and the ability to grow in marginal lands with less water and nutrients. *J. curcas* seeds contain about 25–35% of oil, which can be easily extracted and used both for biodiesel production and as cooking/lighting fuel, medicine, bio-pesticide, and for soap making. Additionally, the seed cake, an oil extraction by-product, can be used as organic fertilizer, combustible fuel, for biogas production (IFAD-FAO, 2010) and also feedstuff after detoxification (Wang et al., 2011).

Indigenous to Mexico and Central Latin America (Maes et al., 2009) *J. curcas* become spread in all the tropical and subtropical zones (30°N; 35°S) of Africa and Asia (Achten et al., 2010). In 2008, 242 Jatropha projects, totalling approximately 900.000 hectares were identified (GEXSI, 2008). More than 85% of the land cultivated is located in Asia. Expectations of increase in production are high, 1–2 million hectares are expected to be annually planted, reaching 12.8 million hectares worldwide by 2015 (Contran et al., 2013, GEXSI, 2008).

However, *J. curcas* is not a "miracle tree" (Contran et al., 2013). For example, since the lack of moisture and nutrients strictly influence plant yield, trade-offs between marginal land reclamation and profitable oil production have to be taken into consideration (Kant and Wu, 2011). For several reasons, both technical and economical, the full potential of *J. curcas* is far from being realized. The growing and management practices are poorly documented. Some of the current strategies used to promote Jatropha may be sub-optimal, which has to be established with proper experimental evidences (Behera, et al. (2010). *J. curcas* is still an un-domesticated tree and its seed and oil productivity is hugely variable.

Water consumption by *J. curcas* is one of the aspects subjected to debate, with conflicting opinions from several authors (Gerbens-Leenes et al.,2009, Maes et al., 2009a) about the crop water use efficiency and the amounts necessary to provide a sustainable yield. The study of

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climatic growing conditions of *J. curcas* in the regions of origin (Maes et al., 2009b) revealed that most specimens (87%) were found in tropical savannah and monsoon climates (Am, Aw) and in temperate climates without dry season and with hot summer (Cfa), while very few were found in semi-arid (BS) and none in arid climates (BW). Ninety-five percent of the specimens grew in areas with a mean annual rainfall above 944 mm yr^{-1}. The mean annual temperature range was 19.3–27.2 ºC. These findings suggest that *J. curcas* although can stand drought has a natural preference for more water than initial estimates would suppose. Behera, et al. (2010) refer that in order to achieve high biomass and optimum yield, irrigation at regular interval is one of the critical input, while standardizing the agronomic practices. The minimum annual average rainfall at which *J. curcas* is known to yield a harvestable amount of seeds is 500–600 mm yr^{-1}.

Like any other forestry or agricultural activity successful installation of the crop depends upon several factors, including the method of plant preparation and the quality of the plants produced.

There are different ways to establish a Jatropha plantation. 1. Planting through direct seeding; 2. Planting through direct planting of hard cuttings; 3. Planting of bare rooted seedlings; 4. Planting of seedlings in poly bags; 5. Planting of cuttings in poly bags.

Each method has its own advantages or disadvantages in terms of labour consuming but the different methods have influence on the establishment of the crop. Propagation from seedlings produce plants with a tap root which confers better fixation and better survival in drought conditions, whereas propagation from cuttings only produce plants with shallow roots. Also the rate of survival of plants produced by seedling transplant is much higher than with cuttings.

In large scale commercial plantations the best suitable method for plant propagation is by seedling transplant and this option has been mostly adopted for allowing plants to have appropriate conditions at initial growth stages and to result in better field establishment (Geply et al., 2011).

The seed nursery area is roughly 0.2% of the plantation area, which in the case of large plantations (>5000ha) become substantial (>10ha). Adequate water supply in this stage is crucial for seedling development (Achten, et al., 2010) and the plants respond well to nutrient supply and quality of growth media (Geply et al., 2011). In order to promote water-saving during the nursery and plantation phases it is necessary to develop an integrated system that includes water-efficient irrigation, agronomic watersaving techniques, and appropriate agricultural management (Wang et al. 2002). The application of additives to improve water retention has been found to be a simple and effective way for saving water. Super-absorbent polymers (SAPs) have been intensely studied in recent years due to their loosely cross-linked network and excellent hydrophilic capacity (Bai et al, 2013, Guilherme et al., 2015, Zohuriaan-Mehr et al. 2010). SAPs can absorb more than a thousand times their original weight in water, and their swelling equilibrium composite can retain liquids even under some pressure (Liu et al. 2009).

Because SAPs have superior water-absorption capabilities relative to traditional absorbing materials, they have been widely used in agriculture, horticulture, bioengineering, biomedicine, water purification, and food storage (Zohuriaan-Mehr et al., 2010). The synthetic SAPs that are widely used in agriculture are mainly polyacrylamide and polyacrylate polymers (Mikkelsen, 1994). One of the commercial products available is Terracottem®. Terracotem® soil conditioner is a physical soil conditioner consisting of a mixture with a base of volcanic pyroclastic rock, hydroabsorbent polymers (mixture of acrylamide and acrylic acid copolymers) and NPK fertilizer with trace elements and growth substances (Terracottem, 2005) developed in 1983 by Prof. Dr. Willem Van Cotthem and a team from the Laboratory of Plant Morphology, Systematics and Ecology at the University of Ghent (Belgium). Main benefits of the product according to the manufacturer are: condition the soil, increase the water holding capacity of the soil, promote faster and better root development, improve plant growth, budding, flowering, fruit and vegetable production, reduce time to maturation, reduce both the volume and frequency of necessary irrigation by up to 50%, increase the ecological and effective use of fertilizers by up to 40%, enable plant growth in degraded, saline or otherwise marginal soils, increase plant survival by enabling plants to survive or bridge periods of stress caused by drought or transplantation.

The main objectives of this study were to evaluate the influence of water supply level and Terracottem® soil conditioners on growth and development of *J. curcas* seedlings in the nursery, as a practise which permit to save substantial amounts of water and to raise better plants for field plantation.

MATERIALS AND METHODS

To study the influence of water level and soil conditioner on growth and development of *J. curcas* in the nursery we established a trial in a glasshouse at the Tropical Botanical Garden in Lisbon, Portugal, which ran from 10 June (sowing date) to 28 August 2010. Minimum and maximum temperatures during the trial are shown in Table 1.

J. curcas seeds originated from Cape Verde (Fogo Island) were sown in plastic trays with 4.5cm x 4.5 cm holes filled with Levington® F2 compost (nutrient content in Table 2) and covered with a layer of vermiculite. Two weeks later the seedlings were transplanted to plastic pots with 2.5 L capacity filled with 1.6 Kg of growth media, consisting of 2:1 parts of vegetable earth (with high organic content) and sand, for which the pF curve was established.

Two types of soils conditioner (Table 3) were applied as recommended by the manufacturer: Terracottem Universal® (TU) and Terracottem Complement® (TC)® in 3 levels: T control (no application), TU2 and TC2 2g per pot and TU4 and TC4 4g per pot. Three watering ratios related to plant available water (PAW) determined by the pF curve were applied: W1 (25% PAW), W2 (50% PAW) and W3 (PAW) corresponding to 100, 200 and 400 mL per pot. Water evaporation from the substrate was minimized by covering the soil surface and the bottom of the pots with aluminium foil. Watering was done manually 3 times a week to maintain the water level at the correspondent target weight per pot on a balance scale.

Four replicates per treatment were used, in 2 blocks, making a total of 120 pots.

The measured parameters on a weekly base after transplanting during five weeks were: plant height (measured from substrate surface till apical meristem) [cm], number of leaves per plant (n), length of major leaf (cm), leaf area (Licor LI-3100C Area Meter) [cm^2] and stem diameter at base (cm). At the end of the trial, (5 weeks after transplanting) measurements were done on: plant fresh weight of aerial part (g), leaves fresh weight (g), stem fresh weight (g). Dry mass of all leaves and stems (g) was determined after oven-drying at 105 º C until constant weight.

Biomass allocation to leaves was determined (Achten, 2010) by the calculation of mean dry leaf mass (=total dry leaf mass divided by number of leaves) and mean leaf size (=total leaf area divided by the number of leaves) for each individual. Total leaf biomass was expressed as a proportion of the total biomass produced in each treatment.

For all measured parameters, data were subjected to statistical analysis using the software Statistica, version 12 (StatSoft Inc.). Factorial ANOVA tested effect of watering level, conditioner treatment and interaction between both followed by Tukey HSD to ($P<0.05$) identify differences

Table 1: Minimum and maximum temperatures in the glasshouse during the trial

Weeks after transplanting	Temperature (°C)	
	Min	Max
1 (24-05 to 30-05)	15.8	32.6
2 (31-05 to 06-06)	17.3	37.3
3 (07-06 to 13-06)	18.7	33.3
4 (14-06 to 20-06)	18.7	37.0
5 (21-06 to 28-06)	19.3	38.4

Table 2: Composition of Levington® substract

Nutrient	Content
pH (H_2O)	5.7
pH (KCl)	5.1
O.M. (%)	0.72
P_2O_5 (ppm)	105
K_2O (ppm)	84
Ca (ppm)	381
Mg (ppm)	197
Na (ppm)	39
Fe (ppm)	73.6
Zn (ppm)	3.0
Cu (ppm)	4.0
Mn (ppm)	132.6

Table 3: Composition and characteristics of Terracottem® conditioners

Composition: Mixture of acrylamide and acrylic acid copolymers with a base of potassium and ammonium, crosslinked with potassium salt 39.5%		
Fertilizers	(N)	5%
	(P_2O_5)	1%
	(K_2O)	4%
Trace elements soluble in water	Boron (B)	0.01%
	Iron (Fe)	1.25%
	Molybdenum (Mo)	0.001%
	Copper (Cu)	0.005%
	Manganese (Mn)	0.03%
	Zinc (Zn)	0.003%
	Growth stimulators	0.25%
	Volcanic pyroclastic rock	49.75%
Physical & physico-chemical characteristics	Bulk density	0,8 kg/l
	pH (1 g/l H_2O)	~7
	Dry matter	96%
	Organic matter	30%
Maximum water holding capacity	Terracottem universal	4500 g H_2O/100 g in distilled water
	Terracottem complement	1000 g H_2O/100 g in distilled water
Granular size x	>4 mm	10%
	3 mm<x<4 mm	20%
	1 mm<x<3 mm	50%
	1 mm<x<0.63	15%
	X<0.63	5%

[1]Terracottem® Universal (original formula with roughly 40% of polymers, 10% of fertilisers, 0.25% of growth stimulators and 49.75% of carrier); Terracottem® Complement (with roughly 7.5% of polymers, 10% of fertilisers, 0.25% of growth stimulators and 82,25% of carrier)

Table 4: Final results for the variables studied (5 weeks after transplanting/7 weeks after sowing)

Variable	Water[1]	Control	Terracottem soil conditioner[2]			
			TU2	TU4	TC2	TC4
Plant height (cm)	W1	12.9 aB	13.0 aB	12.9 aB	13.8 aB	12.7 aB
	W2	13.0 aB	15.6 bAB	13.5 abB	15.6 bAB	15.1 abAB
	W3	16.2 aA	18.2 aA	17.1 aA	17.2 aA	16.7 aA
Stem diameter (cm)	W1	0.6 aA	0.7 aA	0.7 aA	0.7 aA	0.7 aA
	W2	0.7 aA	0.8 aA	0.7 aA	0.8 aA	0.8 aA
	W3	1.2 aA	1.2 aA	1.2 aA	1.2 aA	1.2 aA
Leaves number (n)	W1	3.3 bB	5.0 aB	4.5 abB	4.8 aA	3.8 abB
	W2	5.0 aA	5.8 aAB	5.0 aB	4.8 aA	5.2 aAB
	W3	5.0 cA	7.0 bA	8.8 aA	6.0 bcA	6.2 bcA
Major leaf length (cm)	W1	7.1 aB	8.8 aB	8.0 aB	8.4 aA	7.8 aB
	W2	8.5 aAB	8.7 aB	7.4 aB	8.8 aA	8.7 aAB
	W3	10.1 aA	10.5 aA	10.0 aA	9.7 aA	10.1 aA
Fresh weight aerial part (g)	W1	4.9 bB	8.1 aC	8.4 aB	8.4 aB	6.5 abC
	W2	7.5 bB	11.2 aB	8.5 bB	9.4 abB	9.1 abB
	W3	18.9 bA	25.0 aA	23.2 abA	23.0 abA	21.0 abA
Fresh weight stem (g)	W1	2.5 aB	3.8 aB	4.0 aB	3.9 aB	3.1 aB
	W2	3.9 aB	5.6 aB	4.6 aB	4.9 aB	4.9 aB
	W3	11.6 bB	15.2 aA	15.6aA	13.8 abA	12.5 abA
Fresh weight leaves (g)	W1	2.5 aB	4.3 aB	4.5 aB	4.5 aB	3.4 aB
	W2	3.6 bB	5.6 aB	3.9 abB	4.5 abB	4.2 abB
	W3	7.3 bA	9.8 aA	9.6 aA	9.3 abA	8.6 abA
Leaf area (cm^2)	W1	113.9 bC	172.5 aC	177.0 aB	176.8 aB	143.0 abB
	W2	149.9bB	214.5 aB	158.3 bB	178.8 bB	168.8 bB
	W3	268.1 cA	347.8 aA	343.3 aA	330.0 abA	309.8 bA
Dry weight aerial part (g)	W1	4.9 bC	8.5 aB	7.5 aB	8.7 aB	6.9 abB
	W2	7.9 bB	11.3 aB	8.8 aB	9.7 aB	9.4 aB
	W3	18.4 cA	24.1 aA	22.4 bA	22.2 bA	20.4 bcA
Dry weight stem (g)	W1	1.6 bB	5.4 aB	4.9 aB	5.6 aB	4.5 aB
	W2	3.2 bB	6.7 aB	5.0 abB	5.6 aB	5.3 abB
	W3	10.1 aA	11.0 aA	10.7 aA	10.3 aA	9.7 aA
Dry weight leaves (g)	W1	3.3 aB	3.1 aB	2.7 aB	3.1 aB	2.5 aB
	W2	4.7 aB	4.6 aB	3.8 aB	4.1 aB	4.1 aB
	W3	8.4 bA	13.0 aA	11.7 abA	11.9 abA	10.7 abA

[1]Water: W1 (25% PAW), W2 (50% PAW) and W3 (PAW); [2]Terracottem soil conditioner: TU Terracottem Universal; TC Terracottem Complement. 2=2 g per pot; 4=4 g per pot. Means followed by different letters (small for conditioner and capital for water) are significantly different ($P \leq 0.05$)

between means. Block allocation showed no significant difference in previous ANOVA.

RESULTS AND DISCUSSION

The results for the variables studied at 5 weeks after transplanting are presented in Table 4.

Water level had significant influence over plant growth and development. Maximum water level W3 resulted in the highest plant growth and development, with exception of the number of leaves and stem fresh weight, were W3 and W2 do not differ but are higher than W1. Plants supplied with water level W2 had a significant higher number of leaves, leaf area, and leaves dry weight than W1.

For water level W3 significant differences to control were observed in plants supplied with Terracottem® Universal TU2 and TU4, for the variables number of leaves, leaf area and fresh and dry weight of the aerial parts due to differences in the weight of both leaves and stems. Treatments with Terracottem® Complements TC2 and TC4 only differ to control for the leaf area and for the total dry weight with TC2.

For water level W2 the most significant positive differences to the control were observed in TU2 and TC2 for plant height and total dry weight (due to increase in stem dry weight), and only in TU2 for plant fresh weight (due to an increase in leaves fresh weight).

For water level W1 the highest positive differences to the control were observed, especially in the treatments with TU2 and TC2 for the number of leaves, fresh weight aerial part, leaf area and dry weight of aerial parts.

Stem diameter which is a variable often used to estimate above ground biomass was not influenced by any of the treatments.

Biomass allocation to leaves (Table 5) expressed as percentage of the mean dry leaf mass to total dry biomass above ground was not significantly different to control in any treatment, and the mean leaf size was only higher in the plants supplied with the W3 treatment. The use of the conditioners on the low water level W1 influenced the mean leaf size only with TU4 treatment while in the medium water level W2 was a positive effect of TU2, TC2 and TC4.

The proportion of total aboveground dry biomass represented by the leaves was about 67% in the dry treatment, 60% in the medium water level and only 45% in the maximum water level. On the opposite the stem proportion on the above ground biomass was 33%, 40% and 57%, showing that although the stem diameter is not influenced by the amount of water supply the wood density is higher and plants invest in the formation of more shoots and branches which can store water. These values are much higher than those observed by Achten et al. (2010) in a similar experiment (33-35% for the proportion of leaves to aboveground biomass). The observed increase in leaf area is represented by more leaves produced but also with higher water content.

As we could observe by the results, Jatropha seedlings although can stand water stress at the point of 25% of the field capacity, responded well to the increase of water in almost all parameters studied. At least the medium water level of about 50% the field capacity seems necessary to assure a good growth and development as suggested by other authors (Achten et al., 2010). Biomass allocation of plants in proportion to the above ground biomass changed according to water level.

Table 5: Biomass allocation and mean leaf size of *J. curcas* (5 weeks after transplanting/7 weeks after sowing)

Variable	Water[1]	Control	Terracotem soil conditioner[2]			
			TU2	TU4	TC2	TC4
Biomass allocation leaves (%)	W1	0.67	0.64	0.64	0.64	0.65
	W2	0.60	0.59	0.57	0.58	0.57
	W3	0.45	0.46	0.48	0.46	0.47
Biomass allocation stems (%)	W1	0.33	0.33	0.36	0.36	0.35
	W2	0.40	0.41	0.43	0.42	0.43
	W3	0.55	0.54	0.52	0.53	0.53
Mean leaf size	W1	34.5	34.5	39.3	36.8	37.6
	W2	30.0	37.0	31.7	37.1	32.5
	W3	53.6	49.7	39.0	55.0	50.0

[1]Water: W1 (25% PAW), W2 (50% PAW) and W3 (PAW); [2]Terracottem soil conditioner: TU Terracottem Universal; TC Terracottem Complement. 2=2 g per pot; 4=4 g per pot

The use of the soil conditioners with more polymers, TU2 and TU4, influenced both the production of leaves and the production of biomass and was also influenced by the water level present as expected. The higher effects were observed in the maximum water level which could represent the necessary amount of water to saturate the absorption rate of the compound but it seems that the optimum rate of application should not be above TU2 or TC2. The medium water level (200 mL) seems also an adequate treatment since with the lowest level of conditioners would allow a saving of 50% of water without great compromises in seedling growth and development. These findings are in agreement with previous reported experiments with Terracottem® soil conditioner in pepper (Torres et al., 2008).

CONCLUSIONS

This was the first experiment dealing with the influence of water level and soil conditioners on *J. curcas* L. seedlings growth and development. Despite the references of drought capabilities of the specie results suggested that commercial growing cannot be done without the adequate amount of water in the nursery, to ensure vigorous stands for field transplant, allowing better plant establishment and sustainable production. The use of soil conditioner technology as employed here, with this commercial product, may contribute to save considerable amounts of water and produce more vigorous plants. The application of Terracottem® Universal seems to have a positive influence over plant growth especially when water is short (W1). Highest results however were obtained with the combination of both moderate water supply (W2) and Terracottem® Universal (TU2) suggesting that this may be recommended combi nation of factors for Jatropha in the nursery since it had no significant effect in plant height, stem diameter and number of leaves but positive effect in biomass and leaf area production, suggesting that the volume of water can be reduced to 50% PAW without affecting seedling growth.

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Authors' Contributions

Authors' contributions were equal regarding preparation and conduction of the experiment in which they were involved in all necessary steps. Statistical analysis was performed by Maria Jose Silva. Manuscript was prepared by Mario Santos and revised by Maria Jose Silva.

REFERENCES

Achten, W. M. J., W. H. Maes, B. Reubens, E. Mathijs, V. P. Singh, L. Verchot and B. Muys. 2010. Biomass production and allocation in *Jatropha curcas* L. seedlings under different levels of drought stress. Biomass Bioenergy. 34: 667-676.

Bai, W., J. J. Song and H. Zhang. 2013. Acta Agriculturae Scandinavica. Vol. 63. Pp. 433-441. http://dx.doi.org/10.1080/09064710.2013.797488.

Behera, S. K., P. Srivastava, R. Tripathi, J. P. Singh and N. Singh. 2010. Evaluation of plant performance of *Jatropha curcas* L. under different agro-practices for optimizing biomass – A case study. Biomass Bioenergy. 34: 30-41.

Contran, N., L. Chessa, M. Lubino, D. Bellavite, P. Roggeroa and G. Ennea. 2013. State-of-the-art of the *Jatropha curcas* productive chain: From sowing to biodiesel and by-products. Ind. Crops Prod. 42: 202-215.

Geply, O. A., R. A. Baiyewu, I. A. Adegoke, O. O. Ayodele and I. T. Ademola. 2011. Effect of different pot sizes and growth media on the agronomic performance of *Jatropha curcas*. Pak. J. Nutr. 10: 952-954.

Gerbens-Leenes, W., A. Y. Hoekstra and T. H. van der Meer. 2009. The water footprint of bioenergy. Proc. Natl. Acad. Sci. USA. 106: 10219-10223.

Guilherme, M. R., F. A. Aouada, A. R. Fajardo, A. F. Martins, A. T. Paulino, M. T. Davi, A. F. Rubira and Muniz. E. C. 2015. Superabsorbent hydrogels based on polysaccharides for application in agriculture as soil conditioner and nutrient carrier: A review. Eur. Polym. J. 72: 365-385.

IFAD-FAO. 2010. Jatropha: A Smallholder Bioenergy Crop - The Potential for Pro-Poor Development, Integrated Crop Management, Vol. 8. FAO, Rome, Pp. 1-114.

Kant, P. and S. Wu. 2011. The extraordinary collapse of Jatropha as a global biofuel. Environ. Sci. Technol. 45: 7114.

Maes, W. H., W. M. J. Achten and Muys. B. 2009a. Inadequate data and methodological errors lead to an overestimation of the water footprint of Jatropha curcas. PNAS 2009 106(25) 10219-10223, DOI 10, 1073/pnas. 0812619106.

Maes, W. H., A. Trabucco, W. M. J. Achten and B. Muys. 2009b. Climatic growing conditions of *Jatropha curcas* L. Biomass Bioenergy. 33: 1481-1485.

Mikkelsen, R. L. 1994. Using hydrophilic polymers to control nutrient release. Fertil. Res. 38: 53-59.

Terra Cottem. 2005. Distributor Guidebook September, p. 44. Available from: http://www.fructifera.org/PDF/Distributor%20Guidebook%202005.pdf.

Torres, D., D. Rivero, Y. Rodríguez, H. Yendis, L. D., Gabriels and F. Zamora. 2008. Efectos de un acondicionador sintético (Terracottem®)y un acondicionador orgánico (Bocaschi) sobre la eficiencia del uso de agua en el cultivo del pimentón. Agron. Trop. 58: 277-87.

Wang, H. X., C. M. Liu and L. Zhang. 2002. Water-saving agriculture in China: An overview. Adv. Agron. 75: 135-171.

Wang, H., Y. Chen, Y. N. Zhao, H. Liu, J. Liu, H. P. S. Makkar and K. Becker. 2011. Effects of replacing soybean meal by detoxified *Jatropha curcas* kernel meal in the diet of growing pigs on their growth, serum biochemical parameters and visceral organs. Anim. Feed Sci. Technol. 170: 141-146.

Zohuriaan-Mehr, M. J., H. Omidian, S. Doroudiani and Kabiri. K. 2010. Advances in non-hygienic applications of superabsorbent hydrogel materials. J. Mater. Sci. 45: 5711-5735.