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Evaluation of above-ground biomass and stem volume of three Casuarina species grown in the central region of Saudi Arabia

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Abstract: Three species of Casuarina namely *C. cunninghamiana*, *C. glauca* and the natural hybrid *C. cunninghamiana* X *C. glauca* were evaluated for their biomass production and volume. Seedlings of these species were planted in the year 1982 at initial spacing of 1.5 X 2.5 m in an experimental species trial under irrigation with treated municipal effluent. The experiment took place at the Agricultural Research station of the college of Agriculture at Dirab near Riyadh, Saudi Arabia. During the following years, repetitive selective thinning was applied to the whole experiment. At the age of 16 years, three trees from each species were randomly chosen and felled down. The dimensional parameters and biomass components of each tree were determined. The highest total above ground biomass "TAGB" (400 kg tree-1), as well as the highest merchantable stem volume "MV" (0.37 m3 tree-1) was recorded for *C. cunninghamiana* followed by *C. glauca* (200 kg tree-1 and 0.21 m3 tree-1) then the hybrid (175 kg tree-1 and 0.19 m3 tree-1). Mathematical relationships were established for the prediction of both TAGB and MV using some dimensional parameters (e.g. diameter at breast height, DBH; total height, TH and merchantable height, MH). The correlation coefficients of these relationships were highly significant but differed according to species.

Key wards: biomass, *Casuarinas sp*., diameter, height.

تقويم الكتلة الحيوية و حجم الساق لثلاثة أنواع من الكازورينا في المنطقة الوسطى بالمملكة العربية السعودية

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ملخص : درست ثلاثة أنواع من الكازورينا و هى بالتحديد *C. cunninghamiana* و *C. glauca* والهجين الطبيعى بينهما *C. glauca* ×*C. cunninghamiana* وذلك بغرض تقويم إنتاجها من الكتلة الحيوية و حجم الخشب بها. و قد زرعت أشجار الأنواع المذكورة الناتجة من البذرة فى عام 1980 على مسافات مبدئية 1.5 × 2.5 م فى تجربة لتقويم الأنواع تحت ظروف الرى بمياه الصرف الصحى المعالجة، و ذلك بمحطة الأبحاث الزراعية التابعة لكلية الزراعة جامعة الملك سعود بدِ يراب، بالقرب من الرياض. و خلال السنوات التالية للزراعة طبقت عمليات خف اختياري متكررة على جميع الأشجار بالتجربة. بعد مرور 16 سنة على زراعة التجربة اختيرت ثلاث أشجار عشوائياً من كل نوع من الأنواع الثلاثة و أسقطت، و قدرت مكونات الكتلة الحيوية فوق سطح الأرض لكل شجرة بعد تقدير أبعادها. و قد سجل النوع *C. cunninghamiana* أعلى قيمة لكل من الكتلة الحيوية الكلية فوق سطح الأرض(400 كجم /شجرة) و الحجم التجارى (0.37 م3/شجرة) تلاه النوع C. glauca (200 كجم /شجرة)، (0.21 م3/شجرة) و كان أقلها هو الهجين الطبيعى بين النوعين (175 كجم /شجرة)، (0.19 م3/شجرة)، على التوالي. و قد أمكن استنباط علاقات رياضية للتنبؤ بكل من الكتلة الحيوية الكلية للشجرة فوق سطح الأرض و الحجم التجارى لخشب الساق باستخدام القطر عند ارتفاع الصدر و الارتفاع الاقتصادى و الارتفاع الكلى، و كانت معاملات الارتباط لهذه العلاقات عالية المعنوية إلا أنها اختلفت تبعا للنوع النباتي.

كلمات مفتاحية : الكتلة الحيوية ، الكازورينا ، القطر ، الإرتفاع .

Introduction

In arid zones such as Saudi Arabia, the proper selection of planting species is very important for afforestation under the hot climate with low relative humidity and high evapotranspiration conditions. Over the past four decades, fast-growing species with reasonable water requirements have been the most selected tree species for afforestation in many parts of the country for various purposes. Abo-Hassan and El-Osta (1982) mentioned *Casuarina sp.* among the fast-growing wood species that were planted in Saudi Arabia in the last two decades. In most of the afforestation projects *Casuarina sp.* were successfully used due to their exceptional potential in

afforestation of difficult terrains and capability to stabilize shifting sand dunes, marshy spoils, and as windbreaks and shelterbelts (National Research Council, 1984). Most of the *Casuarina* tolerates extreme heat where summer temperature may reach 47 °C and grow on soils of very low fertility (NRC), 1984. Moreover, Badran and El-Lakny (1978) stated that in countries with no natural productive forests, *Casuarina spp.* deserve attention due to their superiority as windbreaks and their high salt and drought tolerance. Kandeel *et al*. (1982) found that *Casuarina* produces dense wood which is a high quality fuelwood, suitable for poles and beams used for construction and it can be pulped for paper making and particleboard production The mature planted trees therefore, constitute a renewable resource that could be used as a source of wood-raw material required for several uses. Saudi Arabia depends mainly on importing woods and wood products.

The objective of the present study was to evaluate the growth, biomass production and stem volume of three 16 years-old *Casuarina* species namely *C. cunninghamiana* Miq., *C. glauca* Sieb. and the natural hybrid *C. cunninghamiana* × *C. glauca* grown in the central region of Saudi Arabia.

Materials and methods

The experimental material for this study were trees from a sixteen years old experimental species-trial comprises three *Casuarina* species, namely *Casuarina cunninghamiana*, *C. glauca* and the natural hybrid *C. Cunninghamiana* X *C. glauca.* This plantation was established at the Agricultural Research Station of the College of Agriculture, King Saud University at Dirab near Riyadh. The trees were planted with initial spacing of 1.5 X 2.5 m and received treated municipal effluent irrigation. During the life cycle of the plantation, repetitive selective thinning was applied to the whole experiment. At age of sixteen years, samples of three trees from each species were randomly chosen and their total height (TH), merchantable height (MH) and diameter at breast height (D) were measured before they were felled down. Using these dimension parameters the merchantable volume (MV) was determined. After felling and cross cutting of the trees, the above-ground biomass was divided into foliage, stem, branches and sampled to determine their dry weights. Total dry weight of each tree as well as that of its above-ground components were measured and scaled for per hectare basis.

Results

The analysis of variance of the data revealed that *C. cunninghamiana* had a mean stem diameter significantly greater than those of the other two casuarina species (P<0.004); it was 26% greater than either that of *C. glauca* or that of the hybrid. Total above-ground biomass (TAGB) was significantly higher in *C. cunninghamiana* than the other two species (P<0.05). It had also a merchantable stem volume (MSV) which was 49% and 43% greater than that of *C. glauca* and that of the hybrid, respectively (P<0.05) (Table 1). The values of TAGB and MV were 400 kg $tree^{-1}$ and 0.37 m^3 $tree^{-1}$ for *C. cunninghamiana*, 200 kg $tree^{-1}$ for *C. glauca* and 0.21 m^3 $tree^{-1}$ and 175 kg $tree^{-1}$ and 0.19 m^3 $tree^{-1}$ for the hybrid (Table 2). In addition, the best reduced pooled models for predicting both MSV and TAGDB using covariance analysis based on the dimensional parameters, as independent variables, were as follows: TAGB= 25.59 + 0.4186.47 D^2 (R^2= 0.919) and MSV= 0.049 + 0.40 D^2MH (R^2 = 0.996). Mathematical relationships were established for the prediction of both TAGB and MV using some dimensional parameters (*e.g*. diameter at base; D, diameter at breast height, DBH; total height, TH and merchantable height,

MH). The correlation analysis showed that the pooled TAGB correlated significantly (P<0.0001) with both D^2 (r= 0.957) and DBH (r= 0.953) (fig. 1) however, no relationships were found for the TAGB of the individual species with any of the dimensional parameters used

Table 1. Mean values ± Standard deviation for diameter at breast height (DBH), m; total height (TH), m; merchantable height (MH); m and merchantable volume (MV), m^3 of sixteen years old *Casuarina glauca*, *C. cunninghamiana and C. cunninghamiana × glauca*.

Species	DBH (m)	Total height (m)	Merchantable Height (m)	Merchantable Volume (m^3)
C. glauca	0.21 ± 0.012*	15.05 ± 2.01	7.46 ± 2.70	0.19 ± 0.07
C. cunninghamiana	0.28 ± 0.022	14.20 ± 1.21	9.70 ± 1.13	0.37 ± 0.07
C. cunninghamiana × glauca	0.21 ± 0.019	14.25 ± 1.09	9.22 ± 0.47	0.21 ± 0.04
LSD 0.05	0.04	3.00	3.42	0.12

Table 2. Mean values ± standard deviation of foliage, stem, branches and total above ground biomass per tree (Kg $tree^{-1}$) and per unit area (Ton ha^{-1}) of sixteen years old *Casuarina glauca*, *C. cunninghamiana and C. cunninghamiana × glauca*.

Species	Dry Matter			
	Foliage	Stem	Branches	Total
	(Kg $tree^{-1}$)			
C. glauca	33.06 ± 3.60	133.94 ± 37.00	39.86 ± 12.14	206.86 ± 47.02
C. cunninghamiana	79.20 ± 24.03	239.36 ± 59.14	80.54 ± 42.82	399.09 ± 99.84
C. cunninghamiana ×Glauca	24.68 ± 4.20	120.62 ± 18.45	28.02 ± 10.48	173.32 ± 30.68
LSD 0.05	28.44	77.56	52.74	132.12
	(T ha^{-1})			
C. glauca	28.76 ± 3.13	123.198 ± 22.74	34.68 ± 10.56	179.97 ± 40.91
C. cunninghamiana	68.90 ± 20.90	208.243 ± 51.45	70.07 ± 37.25	347.21 ± 86.86
C. cunninghamiana ×Glauca	21.48 ± 3.65	104.939 ± 16.05	24.38 ± 9.12	150.79 ± 26.69
LSD 0.05	24.742	67.48	45.89	114.95

Nevertheless, the pooled foliage, branches and stem biomass were significantly (P=0.0009, P=0.015 and P<0.0001, respectively) correlated with D^2 (r= 0.902, r= 0.771 and r= 0.956, respectively). To a less extent and from other separated correlation analyses, significant correlations were found between few biomass components and the dimensional parameters of individual species. For instance, branches biomass of *C. glauca* correlated significantly (P=0.016) with D^2MH (r= 0.99968) and stem biomass of *C. Cunninghamiana* correlated with D^2 TH (r= 0.99998). Merchantable stem volume (MSV), on the other hand, had highly significant correlation relationships (P<0.0001) with all the dimensional parameters used through pooling of the data of all species in one analysis. It correlated with DBH (fig. 2), D^2, D^2TH and D^2MH (r= 0.959, r= 0.959, r= 0.973 and r= 0.985, respectively). However, for

individual species the relationships between MSV and dimensional parameters were less pronounced. The MSV of *C. glauca* correlated significantly only with D^2TH ($P<0.05$ and r= 0.997) whereas that of *C. Cunninghamiana* correlated only with D^2 (P<0.05 and r= 0.999). The MSV of the hybrid had a highly significant relationship ($P=0.0014$) with D^2MH (r= 1.000) and correlated significant also with D^2 ($P<0.05$ and r= 0.998).

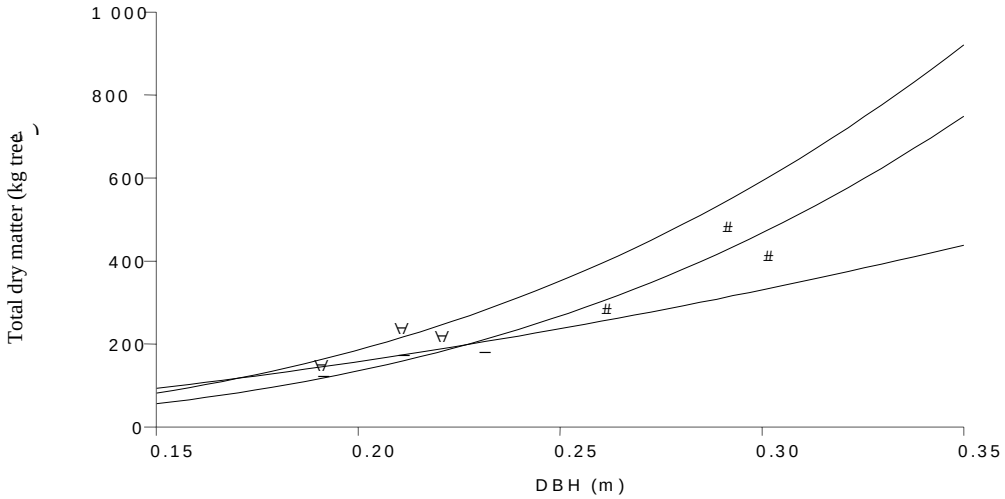

Fig. (1): Relationship Between DBH (diameter at breast height) and total above ground dry weight (kg tree^{-1}) in *Casuarina glauca* __+__ , *C. cunninghamiana* - -*- - and *C. glauca* × *C cunninghamiana* ..#.. after sixteen years of planting in Riyadh region.

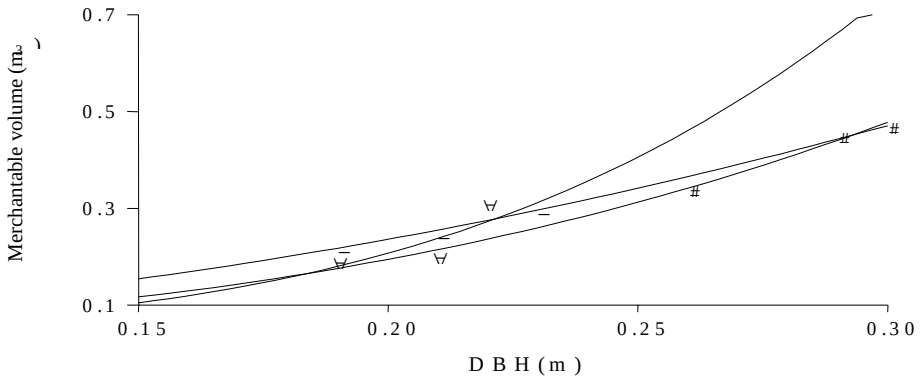

Fig. (2): Relationship between DBH (diameter at breast height) in meters and merchantable volume (m^3) in *Casuarina glauca* __+__ , *C. cunninghamiana* - -*- - and *C. glauca* × *C. cunninghamiana* ..#.. after sixteen years of planting in Riyadh region.

Discussion

The results of the present study show that the 16 years old *C. cunninghamiana* had significantly the greatest values of stem height and diameter compared with either *C. glauca* or the hybrid. The superior growth of *C. cunninghamiana* in the central region of Saudi Arabia has been documented. In a previous research work on the same *Casuarina* plantation when it was about five years old, Aref (1987) found that *C. cunninghamiana* had significantly higher stem height and diameter followed by the hybrid (*C. cunninghamiana* X *C. glauca*) then *C. glauca.* However, after eleven years the later cought up with the hybrid in stem height and diameter. Moreover, Abo-Hassn and El-Osta (1982) reported on the growth of twelve-year old *C. cunninghamiana* grown in the same region in which it had up to 9.75 m stem height and 16.9 cm diameter. Biomass production as a function of both stem height and diameter or either might accordingly be in favor of *C. cunninghamiana* in aforementioned cases. Other *Casuarina sp*. Also showed similar trends as *Casuarina junghuhniana* (Miq.) in Thailand which had stem height and diameter of 4 m and 5 cm, respectively after 35 month of planting date (Virat-Tanpibal, 1986). Casuarina seems to be one of the superior fast-growing tree species in biomass production. In a study with three tree species by Pongsak-Sahunalu and Wiratana-Tanpibal (1985), they found that the growth performance of *Casuarina equisetifolia* at 12-years old was 16.2 cm DBH and 20.3 m height. However, total biomass production of *Casuarina equisetifolia* in seedling stage was moderate among other five tree species when all were planted together in polyculture (Ghatnkar *et al*., 1983).

Accordingly it can be concluded that *C. cunninghamiana* seems to be the best casuarinas species for biomass production in the central part of Saudi Arabia comparing with either *C. glauca* or *C. cunninghamiana* X *C. glauca*. Total aboveground biomass of Casuarina in general can be predicted either from square diameter at base (D^2) or square diameter at breast height (DBH). Merchantable volume of Casuarina can also be predicted from either as well as from square diameter at breast height multiplied by total height (D^2TH) or from square diameter at breast height multiplied by merchantable height (D^2MH). For *C. cunninghamiana,* the best prediction of its stem or branches biomass and merchantable stem volume can be obtained from square diameter at base (D^2). However, more research is needed to compare casuarinas with other exotic tree species in biomass production within the same region and also to evaluate suitability of their woods to different uses.

References

Abo-Hassan, A. A., and M. L. El-Osta 1983. Variation in certain quality parameter of wood from young casuarinas windbreaks trees grown in Saudi Arabia. *Journal of College of Agriculture, King Saud University,* Vol. 4: 53-67.

Aref, I. M. 1987 Provenances Trail of Casuarina sp. In Riyadh Region of Saudi Arabian Kingdom. M. Sc. Thesis. College of Agriculture, King Saud University, Saudi Arabia.

Badran, O. A., and M. H. El-Lakany 1978. Breeding and improving Casuarina for shelterbelt plantations in Egypt. Vol. 2, CSIRO, Canberra, A. C. T. Australia, pp. 573-578.

Ghatnekar, S. D., D. G. Auti, and V. S. Kamat 1983. Biomanagement of

leucaena plantations by ion exchange (India) Ltd. In: Leucaena Research.

Kandeel, S. A. E., J. G. Isebrands, and H. M. Aly 1982. Windbreak grown Casuarina and Eucalyptus trees for unbleached Kraft pulp. Wood and Fiber Science, Vol. 14 (4): 287-395.

NRC. 1984. Casuarina: Nitrogen Fixing Trees for Adverse Sites. National Research Council. National Academy Press, Washington D. C., USA, pp. 118.

Pongsak-Sahunalu, and Wiratana-Tanpibal 1985. Species trials of some terrestrial plants on the tin mine spoils. Seminar on problems and trends to improve mining area, Kasetstar University, Bangkock, Thiland.

Virat-Tanpibal 1986. Effect of chemical fertilizer on the growth of *Casuarina junghuhniana*, Miq. Planted on mine spoil land. Research Report 1984, Raingan wichakan prachampi 2527, Bangkok, Thailand, pp. 567-573.