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Research Article

Seed bury vs broadcast in direct seeding: their effects on the germination of different woody plant species, in a degraded semi-arid area, Southern Ethiopia

Sheferaw Alem*

Central Ethiopia Environment and Forest Research Center, Addis Abeba, P.o.Box, 24536, Code 1000.

*corresponding author:haregitu19@yahoo.com

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Abstract: Direct seeding is considered as an option for afforestation programs to rehabilitate degraded lands. However, scant knowledge is available on the effect of seed sowing techniques on the germination of different woody plants in a semi-arid degraded area. Therefore, the objectives of this study paper are 1) to evaluate the effects of broadcasting vs seed bury on the germination of 15 different woody plant species in a degraded semi-arid area 2) to select woody plants that can result in higher germination percent in the field for restoration projects. To achieve the objectives, a study was carried out in the field, with a randomized complete block design (RCBD). One-way ANOVA, t-test and descriptive statistics were used to analyze the data. The result indicated that the average germination percent for buried and broadcasted seeds were 18.1% and 5.2%, respectively. Among the broadcasted species seeds, *Schinus molle* achieved the highest germination (23.3%) while *Terminalia browni* achieved the lowest germination (0.25%). Among the different species seeds that were buried, *Dolanix regia* achieved the lowest germination (1.5%) while *Sesbania sesban* resulted in the highest germination (64%). The t-test result revealed a significant difference in the mean germination of the broadcasted and buried seeds ($p<0.05$). The ANOVA result also revealed significant differences in the germination of the different families of the species. For most of the studied species (86%), seed bury has resulted in higher germination percent relative to the broadcasted seeds. Therefore, it is recommended that in semi-arid degraded land, it could be better to apply seed bury than the broadcasting when there is an objective to use direct seeding for afforestation.

Keywords: *broadcasting, direct seeding, germination, seed bury, semi-arid*

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Introduction

The forest restoration program has grown up worldwide and for this purpose in addition to tree planting, direct seeding is considered as an alternative option (Grossnickle and Ivetić, 2017). Direct seeding as a restoration option, has a benefit of low cost (no costs for seedling raising, watering and seedling transport, and management) and it can be done quickly over large degraded areas as compared with tree planting (Ceccon et al., 2016). Successful forest restoration is a comprehensive process, and knowledge on which tree species have suitable characteristics for direct seeding is important to the success of forest restoration through direct seeding (Tunjai and Elliott, 2011). The major challenges in direct seeding for afforestation of degraded lands could be the problem of seed germination as it is a complex process. In direct seeding, the seed must quickly recover physically from maturation drying, resume a sustained intensity of metabolism, complete essential cellular events to allow for the embryo to emerge, and prepare for subsequent seedling growth in the harsh environment (Nonogaki et al., 2010). Schmidt

(2008) indicated that species used for direct seeding must be stress-tolerant, have fast germination, establishment and initial growth, and a certain degree of shade tolerance.

The processes that influence the establishment of a seedling from seed through direct seeding are often diverse and complex (Wenny, 2000). The major external factors that affect seed germination are temperature, water, oxygen or air and sometimes light while the internal factor that affects seed germination is mainly seed dormancy (Nonogaki, 2017). Seed bury in spots and broadcasting are the two major seeding practices that are widely used in direct seeding (Fisher et al., 2011). In seed bury, seeds are usually sown in spots prepared by raking, hoeing, or kicking areas free of vegetation and litter and then covered by soil (Barnett, 2014). While, in broadcasting, seeds lie on the ground, exposing them to harsh environmental conditions (Ammondt et al., 2013; Florentine et al., 2013). Broadcast seeding has the advantage of covering a large area efficiently as well as providing a means to seed remote areas and difficult terrain relative to seed bury technique while it has a disadvantage of very low establishment rates (Schmidt, 2008; Ammondt et al., 2013; Florentine et al., 2013).

Direct seeding has resulted in low germination and seedling establishment rates are affected by seeding practices, site conditions, seed predation and vegetation competition (Grossnickle and Ivetić, 2017). Studies indicated that seed bury improves seed germination and seedling establishment relative to the broadcasting technique (Doust et al., 2006; García- Orth and Martínez-Ramos, 2008; Sovu et al., 2010). Whereas, some studies stated that though the broadcasting technique has a disadvantage when combined with the proper site and seedbed preparation and vegetation control, it can be a successful practice for afforestation (Brooks et al. 2009). Pandey and Prakash (2014) in their studies found that soil-buried seeds did not attain higher germination than broadcasted seeds. Similarly, de Souza and Scariot (2014) found that buried seeds did not result in higher germination compared with broadcasted seeds in dry tropical forests. Silva et al. (2017) indicated that seed size along with seeding practice can influence establishment success because seed burial had a negative effect on the emergence of flat seed species compared to round seed species.

Generally, variable results are available on broadcasting versus seed bury on the germination of different species which further shows that many more studies on different climatic areas are necessary. Information on the effects of seeding techniques in a degraded semi-arid area on the germination of different woody plants is scant. The objectives of this study are 1) to evaluate the effect of broadcasting versus seed bury on the germination of different woody plant species in a semi-arid degraded land 2) to identify and recommend those woody plant species that could attain better germination for the restoration of degraded lands through direct seeding for afforestation projects. At the beginning of the study, it was hypothesized that seed bury will result in higher germination percent than the broadcasting technique.

Materials and Methods

Description of the study area

The study area is found in Adami-Tulu Jido Kombolcha Wereda, in Oromia regional state, which is about 164 Km south of Addis Abeba, the capital city of Ethiopia. Geographically, it is located at 7° 58′ 22" Latitude, and 38° 38′ 05" Longitude. The altitude of the study area is 1643 Meters above sea level. The area has a soil type of lithosols and mollic andosols with very shallow depth and very susceptible to water erosion (Tesfaye, 2015). Climatic data for the study area were collected from the Ethiopian Metrological Agency (1990-2018) and the result indicated that the study area has a mean maximum temperature of 26.4 °C and a mean minimum temperature of 13.7°C. The mean maximum temperature occurred from January to June (Figure 1). The study area receives a mean annual rainfall of 775 mm and the highest rainfall was recorded in July and August (Figure 1). The climate of the study area has arid characteristics for most of the year and monthly average rainfall never exceeds evaporation (MoWR, 2006).

Species used in the study

A total of fifteen tree/shrub species that belongs to the family of Fabaceae, Casuarinaceae, Sapindaceae, Anacardiaceae, Caesalpiniaceae, Meliaceae, Moringaceae and Combretaceae were used for the study. The tree/shrub species used in the study were *Faidherbia albida* (Del.) A. Chev, *Vachellia abyssinica* (Hochst. ex. Benth.) Kyal. & Boatwr, *Vachellia tortilis* (Forssk.) Galasso & Banfi, *Vachellia seyal* (Delile) P.J.H. Hurter, *Acacia saligna* (Labill.) H. Wendl, *Casuarina equisetifolia* L., *Dodonaea angustifolia* (L.f) Benth, *Leucaena leucocephala* (Lam.) de Wit, *Millettia ferruginea* (Hochst) Baker, *Schinus molle* L., *Sesbania sesban* (L.) Merr., *Acacia decurrens* Willd, *Delonix regia* (Bojer ex Hook.) Raf., *Melia azedarach* L., *Moringa stenopetala* (Bak.) Cuf. and *Terminalia brownii* Fres. Except for *D. angustifolia* and *T. brownii*, the seeds of the rest of the species used for the study were bought from Central Ethiopia Environment and Forest Research center, Addis Abeba. The seeds of *D. angustifolia* and *T. brownii* were collected from Konso, and Halaba districts, respectively.

Study design and germination test

The study was performed in a slightly degraded area in a field site. The soil was loosened, using a digging hoe, and seedbeds for the sowing of the studied species seeds were prepared. Then the seeds of the species were sown with a thin layer of soil (2 mm), for those treatments that have to be considered as a seed bury. While for those treatments considered as broadcasting, the seeds of the studied species were dropped at the top of the soil and left uncovered with the soil. Overall, for the study a randomized complete block design (RCBD), with four replications for each treatment, each replication having 100 seeds was used. Each replicate has an area size of 2 m * 2 m (4 m^2), and the distance between two consecutive seeds was 20 cm. The seeds were not watered, and rather they are left for nature in which the soil to be moistened by rainfall only. The seeds were sown on 10/06/2017 and their germination was attended till 19/09/2017. This study period was selected because of the presence of rainfall in the selected time (Figure 1). To avoid interference of animals the experimental plot was fenced.

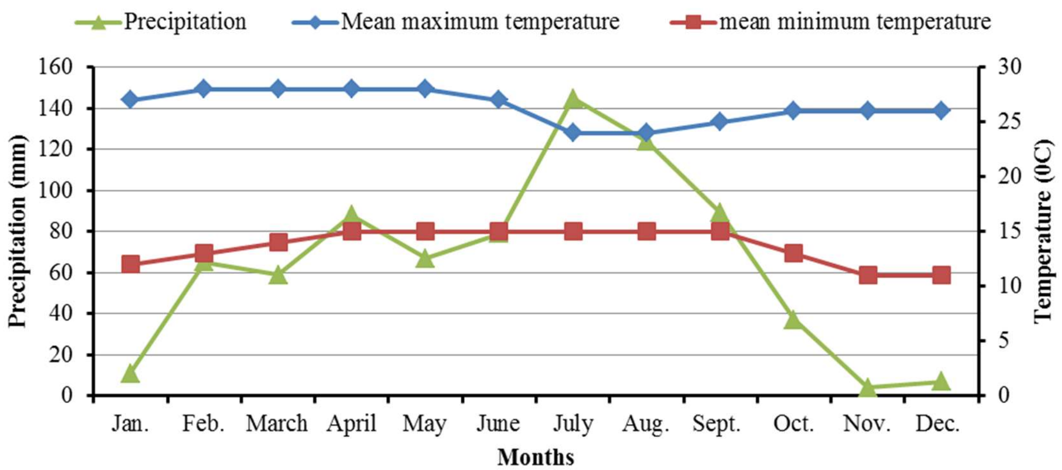

Figure 1. Mean monthly rainfall (mm) and air temperature (ºC) in the study area. (Source: Ethiopian Meteorological Agency).

Data collection and analysis

The germinated (germination was defined as the emergence of the radicle) seeds for each species, that were sown with a technique of broadcasting and seed bury were counted, independently. The germination percentages were analyzed using the following equation (1).

Germination percentage (%) = (germinated seeds/total seeds tested) ×100……………1

In the data analysis, the collected data for the germination of the seeds of the different species was first tested for its normal distribution. For those variables that were not normally distributed, the data were transformed to meet the normality assumption while those fulfilling the normality distribution, the data were analyzed without transforming. One-way ANOVA and t-test were used for the analysis. The software program, SigmaPlot 13 (Systat Software, Inc., San Jose, CA, USA) was used for the analysis of the data. Means were separated using the least significant difference test (LSD) at 0.05 level of significance.

Results

The results on the germination percent of broadcasted and buried seeds of the different woody plant species in a semi-arid degraded land area are presented in Figure 2. The overall average germination percent for broadcasted seeds was 5.2 percent and it ranged from 0.5 percent to 11.3 percent. Among the broadcasted seeds, *S. molle* achieved the highest germination (23.3 percent) while *T. browni* resulted in the lowest germination (0.25 percent). Whereas, the overall average germination percent of the species, in which their seeds buried, was 18.1 percent and it ranged from 1.5 percent to 64 percent. Among the different studied species, through seed bury, *D.*

regia achieved the lowest germination (1.5 percent) while *S. sesban* resulted in the highest germination (64 percent). The results further indicated that the buried seeds for the species of *V. abyssinica, F. albida, C. equistifolia, A. decurrense, D. angustifolia, D. regia, L. lucosofala, M. azadricha, M. ferrugenia, M. stenopetalla, A. saligna, S. molle, S. sesban, T. browni* and *V. toritilis* resulted higher germination percent as compared with the broad casted seeds of similar species (Figure 2). However, the broadcasted seeds of *M. ferrugenia* and *S. molle* have achieved higher germination percent as compared with the buried seeds of *M. ferrugenia* and *S. molle* species (Figure 2). The result on the mean germination percent of the different studied species families is presented in Figure 3. The result indicated that among the different species families of the studied species, the buried seeds for the families of Meliaceae achieved the highest germination (34.5 percent) while the Moringaceae and Combretaceae families achieved the lowest germination (9.8 percent).

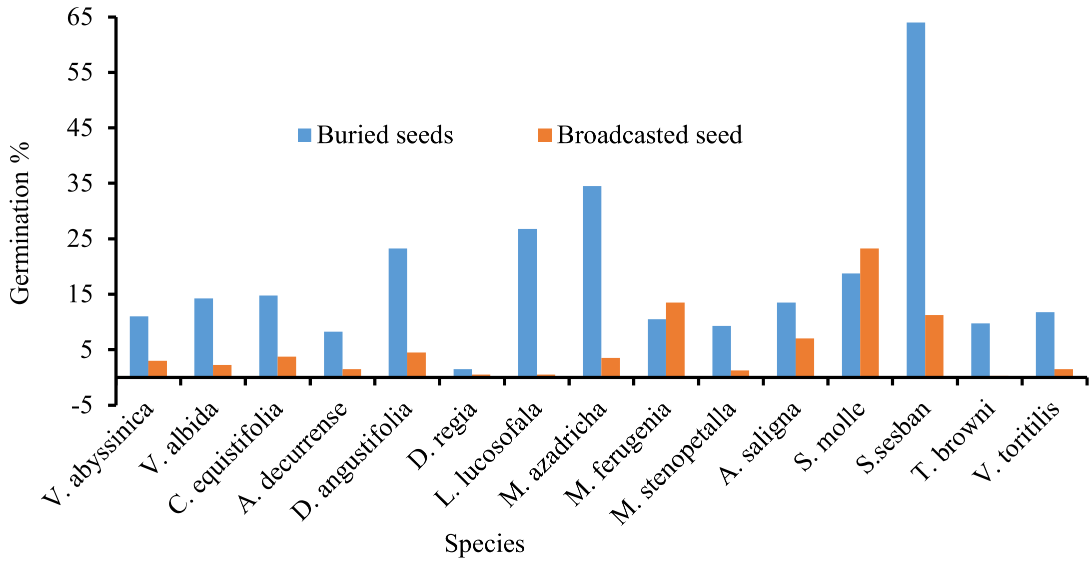

Figure 2. The germination percent of different species seeds that were established through broadcasting and seed bury.

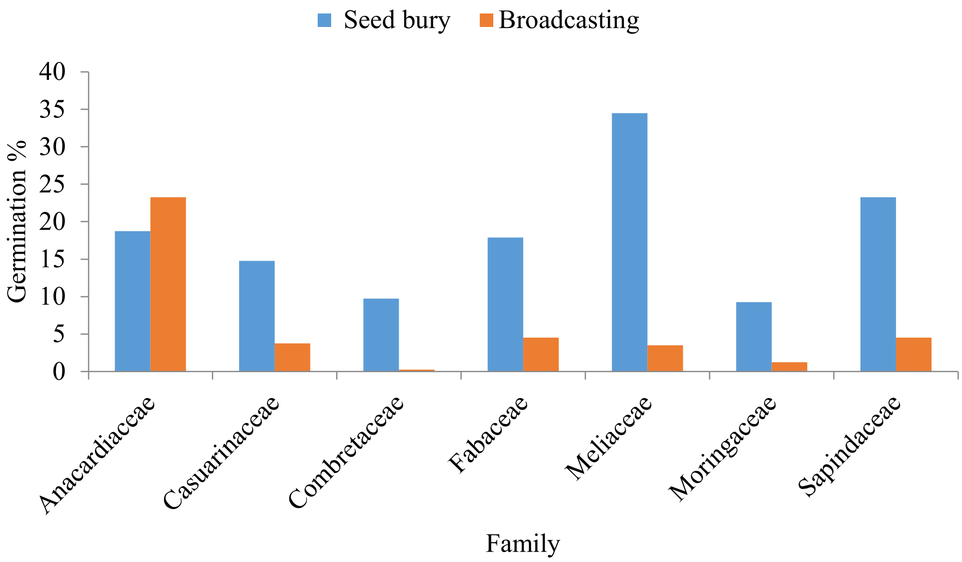

Figure 3. The mean germination percent of different families in which their seeds are buried and broadcasted.

Similarly, among the broadcasted families of species, Anacardiaceae achieved the highest germination percent while Combrtaceae achieved the lowest germination percent (Figure 3). The statistical analysis result indicated that there is a significant difference in the mean germination of all species in which their seeds were buried as compared with the broadcasted seeds (P < 0.05, Figure 4). The one-way ANOVA result also indicated a significant difference in the mean germination of the different families, in which their seeds were, buried (P < 0.05, Figure 5). However, the ANOVA result indicated no significant differences in the mean germination of the different families of species, in which their seeds were broadcasted (P>0.05, Figure 6).

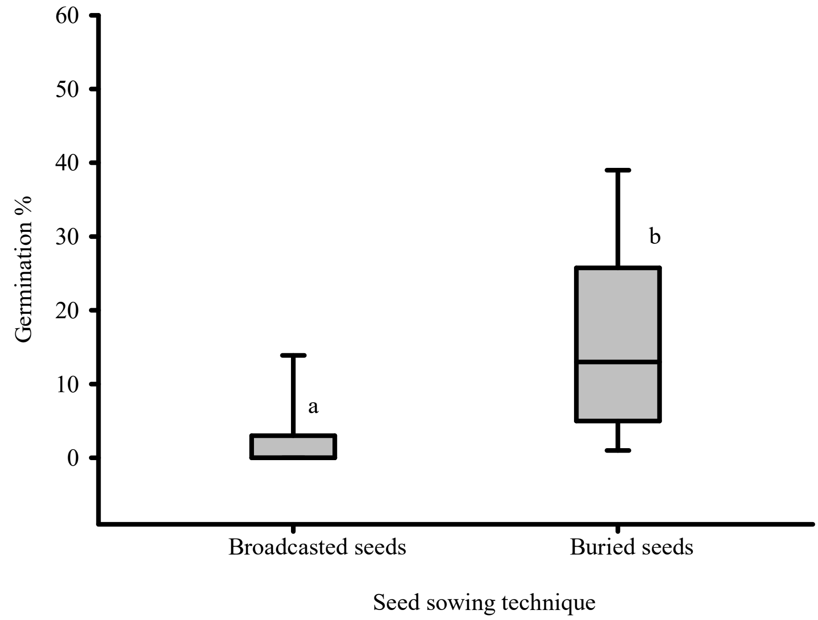

Figure 4. *t*-test result on the mean germination of all species that were broadcasted and their seeds buried. Means with the same letters are not significantly different (P=0.05).

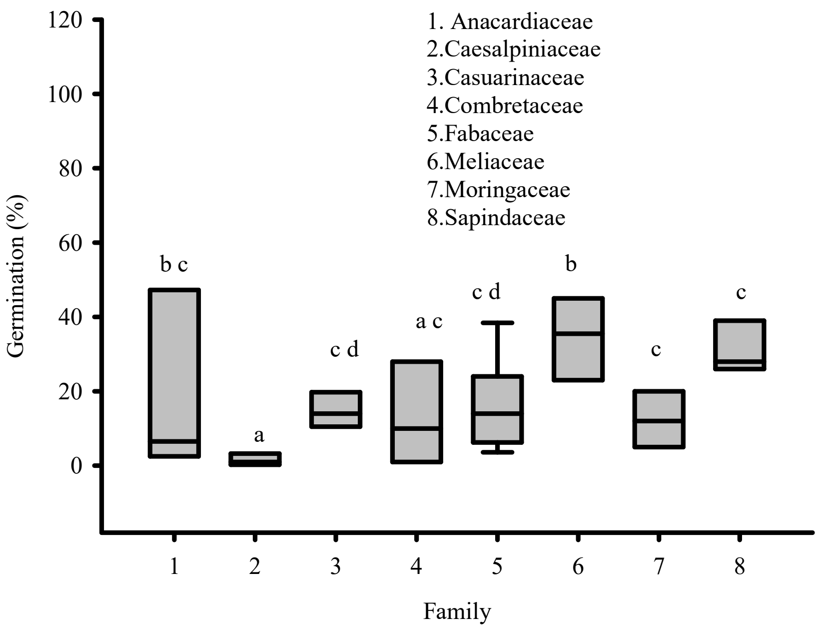

Figure 5. One-way ANOVA results on the mean germination of the different families of species that were established through seed buries. Means with the same letters are not significantly different (P=0.05).

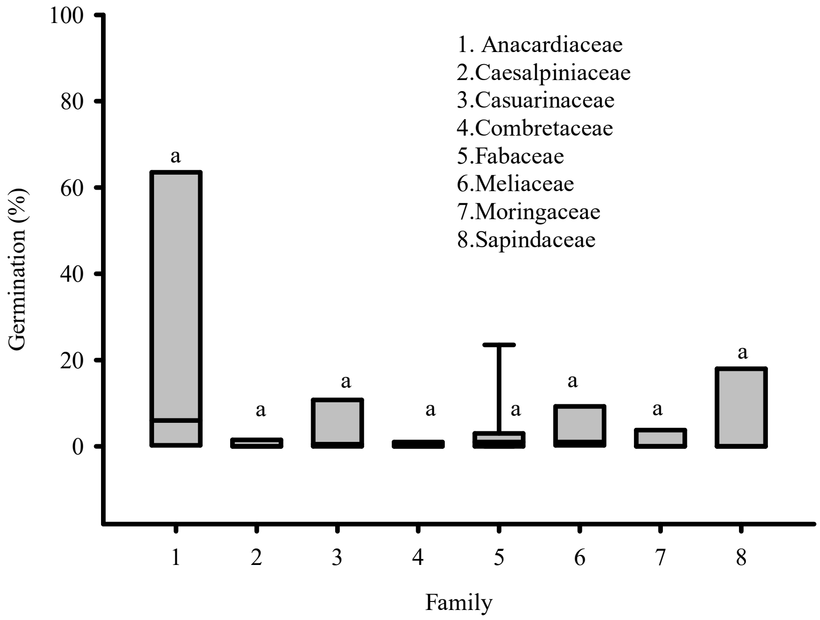

Figure 6. One-way ANOVA result on the mean germination of the different family of species that were established through broadcasting. Means with the same letters are not significantly different (P=0.05).

Discussion

The present study results indicated that for most of the studied species (86 percent), buried seeds achieved relatively higher germination percent as compared with broadcasted seeds. This result could indicate that when direct seeding for afforestation is required, seed bury for most of the studied species could result in higher germination percent than broadcasting. Different studies also indicated that seed burial was improving seed germination relative to the broadcasting technique (Doust et al., 2006; García- Orth and Martínez-Ramos, 2008; Sovu et al., 2010). Similar studies in a tropical species indicated that buried seeds resulted in higher germination percent as compared with broadcasted seeds (Negreros-Castillo et al. 2003; Doust et al. 2006; Sovu et al. 2010). Negreros-Castillo et al. (2003) found out that the germination percent of broadcasted and buried seeds of *Swietenia macrophylla* were 4% and 9%, respectively. While, Sovu et al. (2010) indicated that germination percent of *Keteleeria evelyniana* for buried and broadcasted seeds was 42% and 13%, respectively.

The present study results indicated that the germination percent of broadcasted seeds for *M. ferruginea* and *M. azedarach* were relatively higher than the germination percent of buried seeds. This could show that broadcasting for some species could result in relatively higher germination percent as compared to seed bury. de Souza and Scariot (2014) found similar results in which broadcasted seeds achieved higher germination as compared with buried seeds in dry tropical forests. Similarly, Brooks et al. (2009) in their study indicated that seeds sown with the broadcasting technique have resulted in higher germination percent, in an invasive grassland area. Pandey and Prakash (2014) also indicated that soil-buried seeds do not always attain higher germination than broadcasting seeds. Overall, the present study results indicated that different tree/shrub species established through direct sowing with seed bury and broadcast have responded differently for their seed germination in the semi-arid area.

The reasons for higher germination percent for the buried seeds for most of the species than the broadcasted seeds could be associated with different environmental factors such as soil moisture, temperature, air, perdition, light, etc. Different research results also showed that direct seeding success is primarily related to site conditions that make soil water available during the germination and establishment phases (Kankaanhuhta et al. 2009; Wang et al. 2011; Florentine et al; 2013). Overall, the results indicated that for most of the species seed bury resulted in higher germination percent than the broadcasting. Therefore, it is recommended that in semi-arid degraded land, it could be better to apply seed bury than broadcasting when there is an objective to use direct seeding for afforestation

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